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The Ideal Digital Design Curriculumn: Its Bases and its Content

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There is a potential for the computer to fundamentally change the design process towards a more holistically conceived architecture. One of these directions is the use of software to develop form and the other concerns the use of software that embodies specialist knowledge including design knowledge. Software embodying knowledge will be the capital of the future. As this software becomes more user-friendly it will give architects new power to bring together a multitude of issues in a holistic way without themselves being specialists. A prerequisite for this fundamental change in the design process is an architectural design curriculum that is broader than before and integrates computing across disciplines. In effect, the intention is to educate a new type of Renaissance architect

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Introduction

Architectural design currently proceeds much as it had before the introduction of computers: Designs are developed two-dimensionally on the basis of plans and elevations with the role of the computer relegated to the production of working drawings identical in format to manual drawings. Increasingly, renderings are also created with the help of the computer but are usually created independently, not part of the design process. This assessment is based on a visit to RWDI, the world's leading firm for wind tunnel testing of buildings, which must build a three-dimensional physical model of every building that is tested for wind. Invariably, the design documentation that is submitted consists of two-dimensional plans and elevations only. In schools of architecture there is talk of the use of computers becoming transparent and students moving easily between manual techniques and computers. Unfortunately, this view does not recognize the potential of the computer to radically change the design process in a number of positive ways. There are few examples in the literature and on the Web of academic studios exploring new digital approaches at all stages of design, although the use of digital media for presentations is quite common. Most of the well-publicized digital design studios have been virtual studios with the emphasis on techniques for collaboration between studios over the internet (e.g. Kolarevic et. al. 2000). That is not to say that collaborative design will not become more important in the future and will change the way we design. A review of the state of the art was written by the author with Skip van Wyk (Seebohm and van Wyk, 1999).

The Potential

As Kenneth Frampton (2001) put it recently, we have two "categorically different choices facing the architectural profession today" as regards the way the profession deals with technological proliferation including computers. One is to embrace "the technique of the spectacular without any reservations; to enter, under the rubric of avant-gardism, the generation of unprecedented plastic visual effects, preferably derived from digital processes and dependent for seductive effect on the extravagant use of new high-tech materials". The other choice "is to maintain a distance from the technoscientific whirlwind without denying the potential capacity of advanced technology and the unavoidable effects of its influence". In this second category, I believe, there is a potential to use the computer to fundamentally change the design process and criticism to create an architecture better able to respond to the constraints of a more holistically conceived (on cultural, functional and formal grounds) and sustainable architecture. At the same time there is the potential for architects to halt the loss of credibility that has resulted from architects devolving more and more expertise to specialists. Let me outline the bases for these conclusions and then to follow up with an outline of a curriculum that would support such a view of architectural design and practice.

Bases for Fundamental Change

There are two directions in which digital methodologies promise to substantially change the design process towards a more holistically conceived architecture. One of these is in the generation of form. Another direction is in the use of software incorporating specialist knowledge. This includes software for simulation and testing of different constraints such as structure, energy, lighting and acoustics as well as for social issues such as configurational analyses. (Hillier, 1996). It also includes the use of expert system software that embodies knowledge about how to design such as style and detailing. Consider briefly each of these areas in turn.

Form Generation

That the computer allows the generation and construction of three-dimensional forms previously difficult to conceptualize and build is perhaps the most obvious and published potential influence. We can think of Frank O. Gehry's recent Bilbao Museum and the three buildings that preceded it: the Vitra Museum at Weil am Rhein,. the Vitra Zentrale administration complex at Birsfeld and the Energy Forum at Bad Oeynhausen. Alternatively, we can think of Greg Lynn (1998). Whereas Gehry proceeds from physical models which are scanned, converted to three-dimensional computer models and rationalized for construction, Lynn manipulates forms directly in the computer. Neither, however, uses the computer to generate forms algorithmically. This is an area still largely unexplored.

Curvilinear forms usually indicate the embrace of Frampton's "technoscientific whirlwind" but are not the only possibility. Designing digitally in three dimensions allows one to design in a manner more related to actual construction practices in that construction is more akin to assembling components than shaping and making them. Most components are manufactured off site in large volumes and under controlled conditions. The resulting building therefore consists of hierarchies of assemblies rather than a unique construction. A unique design under the complete control of a single designer is a view promulgated by schools of architecture but it is an obsolete notion, according to Habraken (1998) According to him, building design is a matter of selecting and combining systems. Technical and economic realities have rendered vertical integration of design obsolete. Such a view is exactly in keeping with the structures provided by current three-dimensional modelling systems with their ability to set up hierarchical systems of nested symbols and layers. It also allows one to think in terms of formal vocabularies of shapes. Habraken cites the Rietveld Schröder House as one of the few from the history of Modern Architecture that embodies this principle of designing assemblies that interlock perfectly. The furniture and partitions in the house look as if they were built in when in fact they are completely autonomous and could have been designed separately and by another hand.

Simulation

Holistically conceived architecture means rigorously examining a design from multiple points of view so that each reinforces the other. Simulation means testing for different constraints such as structure, energy, lighting, wind and acoustics as well as social issues reflected in spatial configurations (Hillier, 1996). Historically, the problem of incorporating the constraints of other disciplines has been the difficulty of communicating design intent and of communicating it in the early stages of a design to specialist consultants as well as overcoming the hidden biases of these consultants (Schön, 1983). Simulation software is now, however, becoming increasingly user-friendly allowing the architect to assume control and develop integrated designs incorporating the constraints of other disciplines. A case in point is the Ecotect software package which covers a whole range of disciplines in one package including overshadowing, shading device requirements, solar access, natural and artificial lighting, prevailing wind exposure, thermal comfort, and acoustic response. The lighting component is dealt with by the use of the Radiance software package that is now available also as a standalone desktop version. The latter is one example of simulation software that provides support for judging not only quantitative but also qualitative issues, in this case lighting quality. Another area previously left entirely to intuition and seen only in qualitative terms is the issues of people flows in public spaces and in buildings. Computer based techniques capable of predicting with 75-80-% accuracy are becoming available (Space Syntax http://www.spacesyntax.com). These methods take into account not only origins and destinations of pedestrians but also informal behaviours such as shopping, eating, and waiting, among others.

Expert Systems

An expert system is a computer program that represents and reasons with knowledge (Jackson, 1990). Although the simulation software just described represents specialist knowledge, it leaves the reasoning to the user. Expert systems that assist in design allow designs to be developed by making use of past design experience in terms of style and detailing. Such software would allow design offices to continuously add to their collective design experience and teach novices without having to reinvent the wheel for each design project except, perhaps, in commissions that are intended to break substantial new ground. The collective design experience is not stored in the form of parametric libraries of details, where only dimensions can be changed; it is stored at a meta-level in the form of rules which embody how spaces and components are placed in relation to each other for stylistic consistency and sound construction practice. Such expert systems are not intended to generate designs on their own because that would leave the much larger problems of how to select a suitable design from the huge design space of possible designs. Instead, it is envisaged that a designer would coax such a system with his or her design intentions and the system would fill in the details or suggest alternatives (Seebohm and Wallace 1997).

Knowledge the new capital

Without simulation software, architects are tempted to ignore or deal with many issues only metaphorically. With the development of increasingly user-friendly analysis programs, these specialist domains are becoming useable by architects familiar with these domains but not themselves specialists. As has been pointed out recently, in the future it will not be capital that will be the most important asset but it will be knowledge embodied in software (Armour 2001). Such knowledge, including design knowledge embedded in expert systems, will empower the architect.

Implied in the use of all of the digital simulation and other digital design aids is the development of a fully three-dimensional model of a design on which the various software packages can operate. Each software package must then take the three-dimensional model at its current stage of development and allow the user to help interpret the model in terms of the software in question (e.g. structure for a structural model, light reflecting and transmitting surfaces for a lighting model). Thus designing in three dimensions is a prerequisite for digital design involving simulation though it is still a long way to a representation that realizes Eastman's (1989) vision of an integrated building data base.

The New Curriculum

What do the above digital design methodologies require in terms of a computing curriculum? On the one hand, in order for the practitioner to assume control over his or her designs by means of software embodying a wide range of specialist knowledge, at least in the early stages of design, schools must provide a grounding in a wide range of specialized disciplines. In a sense, the architect must be educated to become a Renaissance woman or man. On the other hand, it requires that there should be a thorough grounding in the use of digital design software tools in a range of courses that might be grouped under the headings of tool using courses, tool building courses (involving some programming) and some courses on computer-based design theory and methods (Gross, 1994). In addition, one should add instruction in the use of discipline-specific software in courses dealing with such disciplines as structures, acoustics, energy, configurational theory and even social/cultural issues and architectural and urban history. Using Gross's categories of courses and adding the discipline-specific courses, a possible computing curriculum for a program like Waterloo's, where there are four years of curriculum for the undergraduate degree and one year for the graduate masters degree, might look as in Table 1. The heavy line separates the undergraduate courses from the graduate courses. In an all graduate program this line would disappear. The position of the line is not fixed in time and could change as incoming undergraduates bring more and more computing skills with them. Also, the order of the courses after the first two could be changed although careful coordination is required so that the requisite tool using and discipline-specific courses have been taken prior to their application in studio.

Consider now briefly each of the categories of courses and then some overall conclusions. Design theory and methods courses can be an independent set of courses but here it is suggested to implement these courses as modules within regular design studios so that the theory and methods can be immediately applied. These modules would focus on specific design methodologies using specific software. Instructors teaching these modules should be regular studio teachers but they must be conversant in the software being used and be in a position to provided encouragement for innovative digital design approaches. Incorporation of these modules in every year of studio instruction implies that it is not a laissez-faire matter of including the use of digital media but of offering specific instruction to explore new ways to discover and exploit the strength of digital design.

Tool using courses are the workhorses of the curriculum where the use of the basic software tools other than discipline-specific software is taught. Rigorously teaching the use of software for design cannot be left to chance even though there are always students who learn well on their own. Most importantly, the software should be taught in such a way that the primary objective is how the software is applied to design and presentation assignments in a way that will outlive the particulars of the software (table 1).

Tool building courses are perhaps the most difficult technically because they involve computer programming but they are potentially very rewarding because they exploit one of the greatest underused strengths of using computers in design. By programming on top of existing 3D modelling applications, such as AutoCAD with the AutoLisp language, it is possible to obtain useful and rewarding results within a single course (compared to learning a computer language and then developing graphics or modelling software). Tool building courses provide access to geometry and forms not built into existing software.

Discipline-specific computing involves learning to use software for various types of simulation such as energy, acoustics, lighting, airflow and structure as part of learning a particular discipline. To be meaningful for design, discipline-specific computing should also be taught by means of small design projects. This suggests teaching such courses

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Table 1. Architecture Computing Curriculum

Design Theory and Methods	*Tool Using*	*Tool Building*	*Discipline Specific*
Year 3 Design Studio with Digital Modules	*Arch 313 collaborative design and virtual distance studio*	–	*Structural*
Year 1 Design Studio with Digital Modules	*Arch 113 digital design: 3D modelling and presentation*	–	*Energy*
–	*Arch 414 GIS and CAD*	–	*Configurational studies*
Year 4 Design Studio with Digital Modules	*Arch 413 Animation and film*	–	*Architectural and Urban history*
Year 2 Design Studio with Digital Modules	*Arch 213 digital design: advanced 3d modelling and digital design techniques*	–	*Acoustics*
–	*Arch 415 Web design and scripting*	–	–
Graduate Digital Design Studios	*Arch 684 Digital Lighting Design* *Arch 684 Rapid Prototyping* *Arch 684 Expert Systems*	*Arch 684 Generative Design (AutoLisp)*	–

wherever possible by specialists who are also designers or, if not, in collaboration with designers interested using the software. This would reinforce the Renaissance ideal at the basis of the curriculum. Now one might well ask, when looking at Table 1, what determines whether a course such as digital lighting design should be listed under tool using courses or under discipline-specific courses. Which category is chosen depends on the balance between design and theory. Ideally all tool using courses would be taught by designers as is the case for the above lighting course. One could argue, however, that all the tool using courses are discipline specific in their own way and that a distinction between tool using and discipline specific courses should not exist. In addition to the traditional technical disciplines, I have added configurational theory as a field of study that ought to be pursued and because software tools are becoming available for this field. Architectural and urban history have also benefitted from the use of computer tools and so deserve to be taught in conjunction with the use of computing tools. One need only look at the enormously successful study of Alberti by Tavernor (1998) which makes extensive use of 3D modelling, drawing and digital photogrammetry.

Conclusion

It has been shown that there is a range of digital software tools emerging to complement designing digitally in three dimensions that will require architects to be educated in a more wide-ranging, Renaissance-like curriculum. This software will allow architects to take more control of design, at least in the easily stages of design, in areas that have increasingly devolved to specialists. At first glance the recommended computing curriculum may appear as an impossible imposition on an already heavily loaded curriculum. One way out of the seeming dilemma is to include the larger part of the curriculum through the modification of existing discipline-specific courses and other courses such as mathematics, geometry, manual drawing (not that manual sketching should be abandoned), traditional photography, whose content could be absorbed, and by offering some of the higher level courses as optional courses. The mix of faculty in any school will have to determine the exact

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strategy and the balance between tool using and discipline-specific courses with a computing component. In keeping with the Renaissance ideal, the more computing is integrated into the curriculum the better, so that one day we can say as Mitchell predicted "what was computer aided design"? (Mitchell 1991).

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