NSBAE
全国高等学校建筑学学科专业指导委员会
National Supervision Board of Architectural Education(China)

2005 建筑教育国际学术研讨会

2005 International Academic Seminar of Architecture Education

论文集

全国高等学校建筑学学科专业指导委员会
沈阳建筑大学
主编

辽宁科学技术出版社

Computing in Western Architectural Education

Jon H. Pittman, AIA
(Autodesk Inc.)

Abstract: Over the past 30 years, significant progress has been made in the integration of computing into architectural education in the U.S. and Europe.However, there is much that remains to be done. The next challenges are to move beyond modeling of pure form to incorporate function and performance and to integrate the disciplines in the building process.

Keywords: Architecture, Education, Computing, BIM, BLM, Modeling

I entered architectural school in the U.S. over 30 years ago. At that time, computers were, at best, a curiosity. Although a number of schools were experimenting with computers, there was not yet systematic teaching or a theoretical framework for computing in architectural, engineering programs, or construction curricula. The state of education at that time mirrored that state of practice. While a few pioneering firms were experimenting with computers in practice, the use of computing technology was then a rarity.

The situation has dramatically changed in Western practice and education over the last three decades. Today computing technology is pervasive and integral to western practice. Construction documents are almost universally produced using computer-aided drafting, engineering analysis of any significance is not possible without computing, most office functions are automated, and construction estimating and scheduling are computerized. Firms routinely use computers for visualization, simulation, and collaboration and many are venturing into new areas such as building information modeling (BIM), design-to-fabrication, and 4D construction simulation.

Given the integral nature of computing to architectural practice, how has education evolved to prepare future practitioners? Students in school today will shape the next three decades of practice. What are they learning and what skills and attitudes will they bring with them as they enter practice? To address these questions, I informally surveyed several educators and industry leaders familiar with architectural and engineering education in the U.S. and Europe. The following is a brief summary of what I learned.

Computers are integrated transparently into the design curriculum. The use of digital tools and digital media has moved out of the computer lab and into the studio. Digital tools are now accepted and entrenched in the design process. Teaching in the studio setting focuses on design skills and concepts rather than the use of digital tools, per se. Digital tools are now transparently supporting the design process. From an educational standpoint, digital tools have faded into the background - as they should. Most studio faculty permit students to use whatever digital tools and techniques are appropriate to solve the design problem presented by the studio.

Students now typically arrive with computing skills - often far more developed than the faculty who teach them. Students are advised to arrive with a working knowledge of computing applications. Most curricula build upon these base capabilities in introductory "skills" courses. These skills courses are the same courses that once taught only tactile skills such as drawing and physical model making-and now incorporate such digital skills as line drawing, digital photo manipulation, presentation, and simple 3D modeling. Some schools offer remedial courses for those students who have not developed skills prior to arriving and tutorial courses that teach specific software applications - often in preparation for professional practice assignments.

In some cases digital skills have supplanted traditional tactile skills such as freehand drawing. The profession has pushed back on the schools and insisted that students develop a balance of digital and tactile skills[①].

Most of the digital tools used in design studios are formal or representational in nature. In other words, they depict shape, with little ability to address performance or constructability. While this fits the nature of many design studios, it has, in some cases, led to aesthetic and formal experimentation that some claim has led to a proliferation of "unbuildable architectural utopias" [②].

In some academic programs, there is a renewed emphasis on "materiality" - or how buildings will actually be realized[③]. This emphasis explores materials, construction methods, fabrication, and assembly techniques. The form-based 3D modeling tools used over the past decade have not had sufficient expressive power to facilitate exploration of materiality. However, new tools, based upon a Building Information Model (BIM) can now support such exploration. BIM tools are commercially available and used at some schools. These tools model buildings using concrete representations of building elements and provide the basis for performance analysis. They will create the possibility of design studios that balance form, function, and performance.

Specialty courses augment and extend the use of digital tools in the design curriculum. To supplement the general use of digital tools in the design studio, many curricula offer specialized courses - often electives - that more deeply address specific topics or application areas. Examples of such specialty courses include:

□ **3D Modeling and visualization**. 3D modeling is considered a standard skill in most universities. However, some offer in-depth courses and specific courses on visualization techniques. Advanced visualization using radiosity and radiance techniques to accurately model lighting are taught at some schools. Additionally, focused courses are beginning to emerge in building information modeling (BIM).

□ **Analysis and simulation**. Analysis of various types is incorporated into many base curricula. Additional analysis courses include energy analysis, lighting, and computational fluid dynamics (CFD).

□ **Fabrication**. A number of schools are offering courses in fabrication - i.e. taking computer models and driving numerically controlled machine tools or other devices to create physical models and representations. This particular specialty course seems to be gaining a lot of attention in U.S. schools[④]. This may well be a result of the interest in construction and materiality.

□ **Generative design**. A few specialty courses are offered in "generative design" - the ability to generate form from a set of initial conditions and parameters[⑤].

□ **Video and digital photography techniques**. A few programs teach digital video and photography as a way of documenting and presenting space.

□ **Collaboration**. Some courses in distance collaboration are taught. Stanford University's Center for Integrated Facilities Engineering (CIFE) has done pioneering work in this area and has conducted joint courses with a number of schools.

□ **GIS**. Some programs teach geographic information systems - often in conjunction with urban planning or urban design courses.

☐ **Computer Programming.** A few courses are offered in "lightweight programming" - databases, web development, Open GL, etc. Most programs emphasize the use, rather than the development of digital tools ⑥.

☐ **Facilities management.** Some programs teach a course in facilities management. Additionally there are a few academic programs that offer entire curricula in facilities management ⑦.

Over time, many of these specialized techniques may be absorbed into the mainstream curricula. Further, it is reasonable to assume that a variety of specialty courses will be developed on an ongoing basis as a reflection of new faculty research interests emerge and new techniques are pioneered.

Architecture programs supply a variety of facilities and students often supply their own laptops and software. Most design studios now accommodate computers for each student - often with wired or wireless networks. It is assumed that students can use computers in any studio. Some schools have desktop computers in the studio - but most are shifting to laptops. They will then focus desktop computing within specialty laboratories. The students typically provide their own laptop computers and software - and many universities require students to come with their own laptop. Universities provide guidance on recommended hardware configurations and software applications students should buy. Students typically can purchase student versions of software at a discounted price. There is, however, a great deal of pirated software used by students.

Schools also provide computer labs - some dedicated to specific purposes, such as rendering or fabrication - and others set up for open access.

A variety of digital design tools are used in western architectural programs. Students are almost universally exposed to Microsoft Office, AutoCAD™ for 2D drafting, Photoshop™ for photo manipulation, and 3D Studio Max™ for form modeling and visualization. Other tools being used are Autodesk Revit, Autodesk Architectural Desktop, Bentley's Microstation, ArchiCAD, FormZ, Rhino, and Maya⑧. Some schools are experimenting with mechanical engineering software such as Autodesk Inventor, Solidworks, Pro-Engineer, or Catia. A variety of analysis tools are used as well - examples are VisualAnalysis for structural, Fluent for Thermal, EchoTech for lighting and thermal analysis. Radiance is used for lighting simulation. Construction management programs use Timberline and Prolog and engineering programs use a host of analysis packages specific to their disciplines.

Architecture schools typically do not standardize on a particular applications - at least explicitly. The way an application is introduced is that a professor gets interested in the potential of the application, develops a course using the application, and students and other faculty adopt the application. Western universities are moving away from core courses that teach specific software applications. They do often teach optional courses or seminars in specific applications. Some schools also teach an AutoCAD-based drafting course to prepare their students for professional practice assignments.

Schools provide a variety of output devices. High quality printers and plotters are commonplace and increasingly - as interest in fabrication increases - schools are providing laser cutters and rapid prototyping devices.

A few schools are experimenting with collaboration technologies and interdisciplinary courses. With the realization that much of the inefficiency in the building process results from hand-offs between disciplines and the reality that design and construction teams are geographically dispersed, some schools have experimented with various collaboration technologies. There are three different kinds of experimentation:

☐ **Virtual Design Studio**[⑨]. Some schools use video conferencing and other technologies to bring critics from several locations into a "virtual design studio". This has the benefits of bringing high quality critics into the studio process and exposing students to working over distances mediated by technology.

☐ **Iroom**. Realizing that one way to address misunderstandings between disciplines is to create hared representations that all parties can see and manipulate, institutions such as Stanford University[⑩] have experimented with very large displays capable of presenting a wide spectrum of information about a project to a diverse group of users.

☐ **Distance Learning**. Some schools are using commercial collaboration technologies to facilitate sharing of information among project members and geographically dispersed faculty[⑪].

Architectural Schools seem to have made more progress than engineering or construction management schools. Computer technology is used extensively in both engineering and construction management programs, but its use is not as integrated. Perhaps because engineering and construction management is not taught in an integrated studio setting[⑫], tools used tend to be disjoint and oriented toward a particular task, such as structural analysis or project scheduling.

While most engineering and construction management programs do not yet typically provide an egrated studio setting, there are some programs that are beginning to pioneer work with building odels. Worchester Polytechnic Institute, in Massachusetts, uses BIM software in its courses to vialize construction and promote collaboration between various participants in the construction process. At Stanford University, Dr. Martin Fischer teaches a BIM course in which students are to odel a building in one of several applications, then demonstrate use of the data in some kind of wnstream analysis application. Thus, construction management and engineering programs are bening to understand and explore the integrated use of building information.

In one respect, construction management and engineering programs are similar to architectural ools. They all reported that their philosophy is to use computer tools as supporting the teaching construction management and engineering concepts. They have integrated the tools into their ricula in supporting roles - in much the same way as architecture programs.

Several new research directions promise to contribute to both the theory and practice of nputing in architecture. The three most promising and interrelated research directions are:

☐ **Relationship of Design and Manufacturing**. Renewed emphasis on constructability and reng buildings has brought forth an interest in understanding manufacturing. The manufactured opposed to built-in situ) content has been increasing and the interest in materiality has spawned y in fabrication and assembly. Further, as buildings and construction processes have become e complex, the role of the architect has become problematic. Interestingly the free-form designs he late'90s and early'00s has also created a motivation for understanding manufacturing and cation since the only way to build some of them was for the designers to become much more ately involved with the fabrication and assembly process[⑬]. All of these threads point to both untanding manufacturing as an analogy for the building process and a potential redefinition of the tect's role as a more central player in the building process[⑭].

☐ **Sustainable Design**. Buildings consume 40% of the world's energy and the construction process generates large amounts of waste. Scrap building materials, for example, constitute a significant percentage of the landfills. With energy resources becoming constrained and the increasingly negative environmental impact of buildings has come renewed interest in green design or sustainable design. One means to sustainable design is to better integrate analysis of the impact of design decisions from a lighting, energy, and material use perspective.

☐ **Performative Design**[15]. Digital techniques to analyze building performance and to a lesser degree synthesize form based upon performance characteristics have existed for many years. However, the tools to do this have typically been disconnected from the digital design tools. Design representations were recreated for performance analysis purposes. Increasingly we will see integration of traditional performance analysis and synthesis tools in the domain of structure, acoustics, lighting, thermal, and life safety. Further, new kinds of performance, such as cost and construction sequencing[16] will be incorporated. Ultimately performance issues of importance to clients such as lifecycle cost and finance may be incorporated.

These three research directions all point toward a more integrated design process - in which architects, engineers, construction managers, and others all work more effectively together to produce ever more complex, yet better performing and more easily constructed buildings.

Some issues remain. While significant progress has been made over the last 30 years, some issues still remain in realizing the full potential of digital tools in architectural education and practice. The vision that many had when computing was nascent in architecture, was that digital technology could provide expressive and analytical techniques to bring together all of the facets of architectural design - form, function, and performance. While we have tools that address each facet, they do not yet work together nor has architectural education worked in an interdisciplinary fashion to bring together all of the perspectives needed to produce great architecture.

☐ **Modeling is still largely focused on form, composition, and visualization**. Although true Building Information Modeling tools exist commercially, the majority of 3D modeling taught in schools (and used in practice) is concerned only with the construction, composition, and visualization of form. Performative, functional, and construction aspects of the building are not typically considered with sufficient depth and rigor.

☐ **Interdisciplinary work is still rare**. While a few schools conduct interdisciplinary courses and projects, this is the exception rather than the rule.

☐ **The level of integration between digital tools is very low**. Digital tools do not typically work well together nor is there much attempt in research or practice to facilitate the flow of data from one tool to another[17].

☐ **Mainstream software is under-represented in the schools**. Because of the preoccupation with form, architectural schools have adopted digital tools with the most expressive character - i.e. those that can create the most novel forms. These are not the tools in mainstream practice. Thus, students are educated using tools they will not likely encounter in practice[18].

Architectural education has made enormous progress in the use of digital tools over the past 30 years. Despite the issues described above, digital tools have come from being a novelty to integrally embedded in the design process. In a little over one generation, digital tools have moved from being hated, to reluctantly embraced, to being entrenched in architectural education. Granted, the tools are not always used to their full potential, but they have become accepted and have "disappeared into the background" . Architectural education is about designing buildings - facilitated by digital tools - rather than about the tools themselves.

Contrast this with the role of building technology in architectural curricula. In May of 2005, the Association of Collegiate Schools of Architecture (ACSA) awarded author and professor[⑲] Ed Allen, FAIA, their Topaz award. Professor Allen wrote an article called Some Comments Concerning Technical Teaching in Schools of Architecture[⑳]. In this article, Professor Allen spoke of the disconnect of architectural technology teaching from the design studio and suggested that technology be taught integrally in the design studio. This has been a debate ranging over many years as academics have struggled to integrate the technical aspects of architecture with the design process.

The use of digital tools has not suffered this fate. Computing technology has become an integral part of the studio design process. The challenge moving forward is move beyond the predominant use of digital tools only used to compose, manipulate, and present form. Today's digital tools create the opportunity to leverage digital technology's expressive and integrative power to bring the function and performance of architecture into balance with its form.

Today's students will shape practice for years to come. Their educational experiences will provide the basis for their understanding and use of digital technology. It is incumbent upon our academic institutions to leverage the progress that has been made over the last three decades in teaching computing to ensure students can realize the full potential of digital tools over the next three decades.

摘 要：在过去的30年中，美国和欧洲在建筑学专业的IT技术教育方面发生了很大进步，但是仍然有很多工作要做。今后的挑战主要表现在：如何超越纯粹的建筑几何模型，把建筑的功能和使用性能集成进去，同时把建筑过程多个专业的工作集成在一起。

关键词：建筑学；教育；IT技术；BIM；BLM；模式

注 释：

① Sharon Matthews, AIA, Executive Director of the U.S. National Architectural Accrediting Board (NAAB).

② Reconstructing the Effects of Computers on Practice and Education During the Past Three Decades. Alfredo Andia. Florida International University. Journal of Architectural Education. 2002.

③ Discussions with Professor Lisa Iwamoto, U.C. Berkeley

④ Larry Sass, architecture professor at MIT, has developed several such courses. In his most new course - Architectural Construction and Computation, students begin with a digital model of a building and explore fabrication and construction. For more information on these courses, see the MIT Open Courseware web site at ocw.mit.edu.

⑤ A few schools seem to be developing courses around "generative methods" . These seem to be methods for parametrically deriving form. Some generative methods may be related to MIT Professor George Stiny's work on shape grammars.

⑥ 20-30 years ago, there was a great deal of debate about educating computational "tool builders" in addition to "tool users". For the most part, architecture curricula now seem to focus on educating tool users. One exception is the graduate program in Computational Design at Carnegie-Mellon University (CMU), which is specifically designed to educate "tool builders". See www.arc.cmu.edu.

⑦ The International Facilities Management Association (IFMA) recognizes eight degree -granting programs in facilities management. See www.ifma.org.

⑧ Architectural IT and Educational Curriculums, A European Overview, Hannu Pentillä.

⑨ Cornell University tried this in the late 1990s and others continue to experiment with techniques for mediating distance with technology.

⑩ Stanford Center for Integrated Facility Engineering (www.stanford.edu / group / CIFE)

⑪ Dr. Janine Clifford, of Harvard University's Graduate School of Design lives in Honolulu Hawaii and teaches in Cambridge Massachusetss. In the Fall of 2004, she ran an urban planning studio where the students used Autodesk Buzzsaw (TM) and DWF Composer (TM), among other tools, to allow her to work with them remotely from Hawaii while they were based in Cambridge, MA (a distance of over 9,000 miles)

⑫ Interestingly, some engineering educators are concerned that engineering is too reductionist and not comprehensive enough and are advocating that engineering courses be taught in a studio setting similar to architectural design - in which the student is responsible for addressing a design problem in a comprehensive fashion.

⑬ Many are fascinated by the blob-like forms produced by Frank Gehry. The more interesting story is of how those forms are actually realized. Gehry has had to make digital representations that span a spectrum from form to actual performance and manufacturing - thus using digital information through the entire process of realizing the building.

⑭ Refabricating Architecture. Stephen Kieran and James Timberlake, both professors at the University of Pennsylvania, explores the analogy between manufacturing and architecture.

⑮ Branko Kolarevic, of the University of Pennsylvania coined this term to mean - very broadly — both performance analysis and the generation of form based upon performance criteria.

⑯ So-called "4D CAD" has been pioneered at the Center for Integrated Facility Engineering (CIFE) at Stanford University (www.stanford.edu / group / CIFE). 4D CAD ties a three-dimensional building model to the construction schedule, allowing stakeholders to see how the building will be sequenced. The benefit to this approach is that conflicts and misunderstandings can be detected and resolved earlier in the building process. This kind of performance analysis is an example of the level of integration that can be achieved.

⑰ Academic institutions can help address this problem by looking for ways to actually demonstrate use of tools in an integrated fashion - such as the modeling course taught by Martin Fischer at Stanford. This can lead the way for both practitioners and software developers to understand specific needs for integration as a step toward developing practical interoperability solutions.

⑱ The mainstream software vendors bear some responsibility for this. As the mainstream tools become more expressive, the rationale for the imbalance between tools used in practice and those used in school will disappear.

⑲ Professor Allen has taught architectural technology at MIT, University of Oregon, Yale, University of Washington, and Montana State and has written several books on architectural technology.

⑳ ACSA News, May 2005.