international journal of design computing 2004 Vol 7

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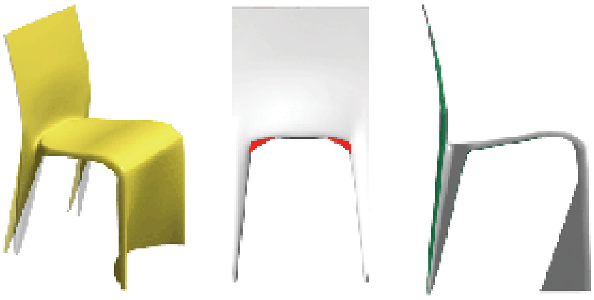

Ditching the Dinosaur: Redefining the Role of Digital Media in Education

Thomas Kvan, Earl Mark, Rivka Oxman, Bob Martens

We are experiencing qualitative developments that are substantively affecting several facets of design education. Professional relationships, construction techniques, buildings, materials, design tools and ways of working are changing rapidly. Of particular interest to us in this paper is the role of digital media in schools of architecture and our understanding of architectural education. We refer to digital media here as encompassing its use in as a basic recording and drawing medium as well as the more progressive use of computational logic applied to design.

The evolution of contemporary digital media and networked communications are among several technological and cultural developments that are creating challenges for architectural education. In this paper we examine the content and character of these developments, sketch some of their theoretical underpinnings, and identify their potential impact on curricula. We propose that one way in which to reformulate educational objectives is to consider what we have referred as the techno-cultural status of the new media vis-à-vis architecture and its educational foundations. How does a new technology find its way into the design culture of a school, and to what degree does it reflect a fundamental shift in our attitude toward architectural education? We intend this position paper to reflect on recent developments and we hope that it will spark discussion online here at IJDC and elsewhere.

Digital media

The teaching of architecture has always related to theories and media of representation (Alofsin, 2002, Charlton, 1973). Digital technologies today are currently challenging both architects and educators to formulate a new understanding of the design realm. We believe that computers have changed, and continue to change, the way we think and represent design. This pivotal situation of on-going developments demands a critical perspective upon changes occurring in the curriculum.

Earlier works have already indicated that digital media have a significant role in evolving patterns of thought and paradigms in architectural design (Mark et al., 2001, Mark, 2000, Novitski, 1987). In recent years, a number of publications have explored and emphasized the intimate relationship between the media and the conceptualization of architecture (Mitchell and McCullough, 1991, Mitchell, 1990, Suwa and Tversky, 1997). Such a deep relationship between design thinking, architectural theory, design computation and digital design as it was formulated more than ten years ago must now be reconsidered in the light of the dramatic developments in both the design potential of current computational technology and the communications revolution of the Web. The implications of wired digital practice are substantially greater in the near future than in the recent past. As educators, we have an obligation to prepare our students, the next generation.

It appears to us that a first basic step in this important reformulation is to identify obsolescence in former paradigms. For example, digital design methods are mired in the past. Designing with CAAD started by mimicking conventional tasks and skills of paper-based traditional design processes, in particular the solving of discrete mathematical or data manipulation problems (Mitchell, 1977). The concept of layering now prevalent in drafting systems was derived from overlay drafting (Stitt, 1984), a technique that came about when dimensionally-stable Mylar was widely available. Yet, the mindset that digital tools are simply electronic versions of analog systems hobbles professional and pedagogical development. Likewise, the conceptualization of digital design tools simply as computational devices that apply mathematical manipulations to digital data (Cross 1977) is obsolete as developments in digital communications have revealed. As in practice, educational programs have fashioned themselves to these cultural conceptions of the "tool paradigm". Most professionals and many schools still consider the computer as filling an ancillary and service role in both the educational and the architectural design process, remaining far from the centre of the notion of architecture itself. The reality of evolving new paradigms in practice as well as in the cutting edge of theoretical production is rendering obsolete this pragmatic and utilitarian view of digital media.

New paradigms may be forthcoming in which digital media are considered as environments for the exploration of new intellectual and theoretical directions, They are characterized by the complete integration of the media with the conceptualization, realization, communication, production and habitation of designs. This new condition of integration is now beginning to emerge with sufficient clarity that we can begin to reconsider educational paradigms of the digital era.

In the following sections we consider the theoretical underpinnings of this emerging new paradigm, we investigate the pedagogical implications, and we discuss the potential impact on educational curricula.

New theoretical design paradigms

In the teaching of architecture, it is clear that theory develops with media. Each medium brings its assumptions, opportunities, affordances and challenges. In days past, schools of architecture taught 'descriptive geometry' (Lee and Reekie, 1949). The course was used as a means to inculcate a discipline to design through a particularly rigorous Euclidean understanding of form and space. The use of traditional media has always proscribed modes of teaching the subject. For example, the introduction of paper in the fifteenth century led to an intellectualization of the subject of building, leading to the notion of architecture' as we know it today (or perhaps knew it in the twentieth century) (Wigley, 2001). The addition of geometric projection advanced manipulation of form and allowed more complex forms to be described and hence investigated and communicated. The engagement of drawing by hand is, we argue, not replicated in the digital world. The process of redrawing disappears when zoom, copy and paste functions are available. It is self-evident that bringing computers into the studio must move past the automation of drafting, although being self-evident has not allowed us to fully act. We must shed the burdens of the dinosaur that is the analog paradigm.

The act of drawing allows the designer to explore opportunities (Robbins, 1994). Drawing has come to be seen as synonymous with design. Through drawing and redrawing, the designer develops and extends the possibilities of a design, yet each drawing is discrete, complete in itself, yet incomplete in as far as the design cannot be understood in the single piece of paper. Digital descriptions can be connected parts of a larger whole. The act of drawing digitally is different to that of drawing on paper. A digital description builds upon and extends other descriptions; through databases a digital line can mean more than a graphite line. Digital form can be responsive to complex site and programmatic constraints. One configuration can be digitally modeled and then dynamically modified in a controlled or interactive process. This enables the creation of shapes that can automatically respond to changes later in a design process. A digital drawing is not complete in itself but gains greater potential through its coexistence in the media with other representations.

The medium of digital design has several defining characteristics, among them that material can be stored, accessed and reused; collaboration is enabled as descriptions are freed from the encumbrance of place; and that designs can be described parametrically, with examples instanced, not discretely drawn. Digital tools also allow us to examine the cognitive process of design. Our traditions, as passed on in studio teaching today, are framed in the assumptions of hand drawing. The discourse of architectural process and image is limited by the nature of mark and trace.

Analysis and simulation methods can be integrated with geometrical manipulation, and 3-D modeling (Brown et al., 1995). Furthermore, formal, technical, and economic implications of design modifications can be evaluated and accommodated when needed during the design process. Such advanced digital performance can also have a dramatic effect on the coordination of interdisciplinary design teams. The geometry of all components and sub-assemblies of a design can be updated automatically in coordination with the overall configuration (Kalay, 1998). Digital tools that bring control of data shared by the design team: the architect, the engineer and the construction management can ensure continuity from generation to manufacturing. Communication of the design to collaborators is more than just passing around the file but a matter of supporting collaborative intentions (Kvan, 2000). Such advanced paradigms go beyond design itself to introduce digital culture in the constitution and communications of remote agents. These advanced levels of performance in design-build teams are also demanding time in the new educational program yet are seldom accommodated.

It is no longer a case of trying to merge computing tools with architecture, but the need to find a new understanding of architecture through the tools. This needs to be conveyed to students at the start of their careers, not introduced just before they graduate in advanced classes. The studio is the forum in which these paradigms and theories can be tested so the curriculum of a design studio is central to the integration of digital ideas to architectural education. We have adopted aspects of digital design, such as geometric modeling and rendering, but not the implications of it. The current obsession of architecture as graphic image has reduced discussion of CAAD to digital design as image processing. We are focused on drawings and images, not substance: data in all its forms, graphic, text, numeric. This leads us to propose an understanding of architecture not as an instantiation of bricks, timber and glass but as a frozen data, embedded knowledge, and, thus, theory materialized. The data embedded in manual drawings are lost and replaced with data generated during construction. Things have changed; for example, digital tools bring control of these data back to the designer and ensure continuity from generation to manufacture.

Pedagogical Movement

The teaching of "design" has been a core topic within architectural studies. Design as the acquisition and composition of knowledge, however, has never been articulated until recent times, in large part due to the dissemination within our culture of an appreciation of data and knowledge acquisition processes of digital devices. While the acquired knowledge and experience concerning design education and design itself does not age as quickly as in many other disciplines such as electronics or informatics, that architectural knowledge has a shelf life is increasingly pertinent.

Computer technology was introduced in the field of architecture with great optimism that we could automate significant portions of the tasks in design (Cross, 1977). Early systems were intended to take over quantification of materials; generation of plans through allocation of activities in optimized configurations; and calculation of a variety of engineering data (Mitchell, 1977). Digital tools gained credence slowly and the optimism often turned to disappointment. Systems were expensive and temperamental, benefits were difficult to realize, tasks became more cumbersome, education failed to gain enlightenment.

Two decades ago, however, a broader use of computer technology in design work emerged with the advent of cheaper desktops. At first, analog conventions were simply transformed into digital counterparts. Drafting systems proliferated. This cannot really be regarded as digital design as it is just the digitalization of an analog input. In terms of ongoing evolution this has rapidly changed with computing capacity widely available now. We are now teaching a generation who did not know a world without computers. Of course, there are remarkable differences in literacy and even students teaching their teachers special skills is not an uncommon phenomenon. When computation becomes ubiquitous, is present in building components as well as on the design desktop, then the need for an understanding of digital potentials goes well beyond drafting and rendering. The discussion of skills versus content becomes meaningless.

These changes have been paralleled by an extended discourse in pedagogy. Early in the history of digital design, attempts were made to explore well-founded pedagogical approaches. Today, associations of those involved in teaching CAAD have been founded in all regions of the world in support of this process (Novitski, 1987). Teachers have realized a wish to exchange experience and were looking for a forum in which to keep track and discuss design teaching.

The development of digital design teaching has not been in isolation. In 1945, Joseph Hudnut at Harvard estimated that the teaching of architecture required over twenty years of schooling if all topics were to be addressed adequately. We estimate that today the period of formal education would extend to over forty if we were to cover all topics appropriately. While this is obviously impractical, important changes have been made to curricula worldwide in the last decades to accommodate new demands, opportunities and potential in construction, professional and process. As a result, a number of additional subjects have been introduced in architectural curricula. In parallel with this, the distinction between these subjects and design studios has disappeared at many schools. Digital design has been caught in this evolution as well.

On the one hand, increasing numbers of schools introduce courses in digital tools, while on the other, the discussion broadly acknowledges that the tools should not be segregated into discrete classes but need to be part of the general discourse of architecture (Mark et al., in press). Increasingly, there is the perception that the teaching of subjects related to CAAD does not make sense any longer. It isn't ruling out the teaching of CAAD per se which is the issue, but rather the integration of computational design methods into the design culture as a whole. This can be enhanced by focused courses on computer based visualization and analysis or studio, but the key point is that digital media need to be reflected holistically throughout the curriculum. This is not a new situation for architectural education, of course. The Bauhaus made the synthesis of the explicit (the craft) and the tacit (the art) central to their curriculum (Wingler, 1969).

The Bauhaus curriculum

For every design task the Bauhaus-students were guided and supported by a craftsman and an artist ("master of form"). This procedure was based on the consideration that the craftsman did have enough creative potential to master artistic problems and solve the problems arising, but also that the artistic educator did not provide enough technological knowledge to see the students through the problem.

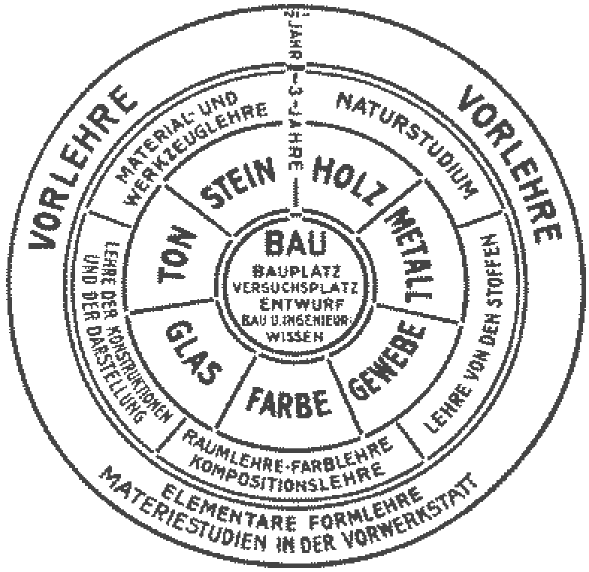

Figure 1: The Bauhaus curriculum 1922

The curriculum was restructured to support students in their exploration and integration of the craft and the art. Schematically, the curriculum was constructed in concentric circles, as elegantly illustrated in Figure 1. Here, the building is represented at the core of this scheme. In concentric rings beyond this are displayed the working materials (glass, clay, stone, wood and metal), and key properties to be manipulated (fabric and color). Students were introduced to these in workshops. The third ring identifies the learning of materials and tools, the study of nature, material science, space-colour-composition, construction and representation. These represent the integration of the issues in the second ring.

The outer ring identifies the starting point for a student, whose goal is to progress into the inner sanctum of architecture. The first step in architectural education was the "Vorlehre" (preliminary learning) in which newcomers experienced a broad introduction by way of an elementary study of form and material. This exposure was conducted largely in the workshop through a hands-on activity of making, drawing upon craft and art immediately. A revised curriculum model of 1937 illustrates in English the same idea.

In order to support this new curriculum, a new generation of teachers had to be educated, so the Bauhaus undertook to school its own. The goal, as Gropius later stated, was to produce teachers who unified both capabilities in one person. It is interesting to remember that one of the first was Marcel Breuer.

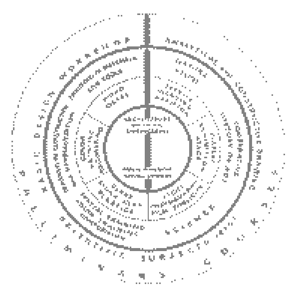

Figure 2: The Bauhaus curriculum 1937

In this example of the Bauhaus, we see a strategy to integrate both the technique (craft) and the content (art). The division of digital skill teaching into one class and architecture into another, common in schools of architecture today, reinforces the idea that craft and art are discrete and divisible. Rather then teaching modeling and rendering as a set of techniques as we still currently do, we should develop new strategies that demonstrate the impact of media techniques in understanding the way designs can be visualized and processed in order to support design thinking. This can occur in focused courses based on conceptual and analytical approaches and in studio.

Furthermore, digital and communications media are enabling new kinds of design thinking processes. Today these media already support two contradictory tasks: on the one hand, they enhance creativity and intuition through ambiguity and abstraction, and on the other hand, they capture and control complexity, as well as providing dimensional precision based on real physical materials.

Parametric design is an example of such an emerging field of digital design based on the development and sharing of geometric relations of complex shapes (Burry and Murray, 1997). The idea behind parametric design is that one can manipulate a particular shape or form and study many alternatives by changing the variables, or parameters, defining the geometry of an object or assembly. Some typical examples are related to designs that are based on complex organic shapes. In addition, design methods that are parametric in character have already been adapted in definitive professional work, such as in the organic shape of the Swiss Re Tower in London (Foster and Partners), the parametrically varied trusses of Waterloo International Station (Nicholas Grimshaw and Partners) and the resolution of a complex triangulated structure at The British Museum Great Court roof (Foster and Partners).

Design Curricula

The integration of computers into design curricula varies according to the talents, institutional culture and opportunities provided within different schools of design. This paper doesn’t presume to put forth a common educational strategy. Rather, we attempt here to make some broad distinctions and to identify new challenges that may be viewed as evolutionary with respect to trends over the last ten years.

Assumptions about the general categorical breakdown of computer related courses.

As suggested in the introduction, there is a changing climate of computer uses in design schools that reflect their wider proliferation in higher education. For examples, business schools distribute case study material incorporating videotape interviews and other graphics presentations over the Web. Schools of education target computer based educational modules with interactive graphics for some levels of learning. The biological and physical sciences use computer graphics simulation. Highly advanced and computational intensive three-dimensional imaging is an ongoing area of research and development within schools of medicine. Computer aided design and CNC are completely at home within schools of engineering. The use of the Web, visual materials and digital historical archives are now firmly established within the humanities. Students entering a university program today may well be expected to engage this world of computer based information interactively and routinely, as well as submit work and communicate with their professors in some local computer mediated venue. MIT recently announced an initiative to place all of their courses on the Web. Many institutions are exploring how to handle and archive the large bodies of digital materials resulting from this shift from a paper-based to a computer text and image-based curriculum.

In this new environment, the mere presence of computer use in a course signals nothing distinct. Basic preparation for entering into this educational setting begins with many students prior to higher education, especially as facilitated by rapidly expanded uses of the Internet in pre-university settings. As courses using computers become the norm in higher education and no longer may suggest anything novel, some further distinctions may be helpful with respect to their uses in design education. We identify courses that:

1. employ computers for general use, not an especially novel condition;
2. apply “digital media”;
3. engage “design computation”; and
4. advance “design theory and computation”.

1. **General Computer Use:** Courses where computers are used are rapidly becoming, if not already, the normative model in higher education. This typically includes the collection and distribution of assignments on the Web or through the use of centralized file servers and related educational toolkits, communications through email and live “chat room” applications, and in some cases, local or distant video telecommunications. The skills needed to use these technologies are a basic part of general literacy in higher education. Coursework depending upon these technologies are not necessarily investigative, or innovative, with the technology itself.

2. **Digital Media:** A growing number of subject areas may refer to the use of “digital media”, a term that conjures up the notion of a counterpart to traditional paper based media, where images are stored and generated by means of a computer, and yet where the conceptual orientation may be similar to that related to traditional media forms. This is not the more encompassing use of term “digital media” as suggested at the beginning of this paper. For example, a student may modify a digital photograph with an image edit program such as Photoshop in a way that is similar to how an earlier generation of students may have collaged a photograph and a hand drawing. To be certain, the Photoshop approach offers a range of effects and color change operations heavily dependent upon intensive computer processing and which depart from traditional paper based methods, but the end result might conjure up images from an early 20th century Bauhaus advertisement course as much as any contemporary and digitally based course.
   In somewhat less absolute terms, we might also view the use of three-dimensional computer aided design models as having a counterpart to more traditional paper, board or wooden models in the design studio, The computer based models may offer distinct advantages in terms of the ease of repetition and scaling of some design elements, or the quick generation of perspective or axonometric projection, or even the rendering of the model in various lighting or light energy algorithms. These modeling techniques may offer advantages in terms of the speed of generating and changing three-dimensional forms. Yet, they relate directly to the envisioning of that form as relatively inert geometrical objects as was the case in the more traditional media based design studio. The background computation processes would seem relatively transparent to the typical end use designer. The icon driven command menus of the image processing and CAD modeling programs have their roots in the longstanding metaphors of the traditional design studio (e.g., a pencil icon in Photoshop for drawing a line, a spray can icon for drawing a spread of evenly colored pixels, a T square for defining a three-dimensional construction plane in a CAD system, layers represented in the symbolic icon of a trace paper stack to organize information). Differences between computer and traditional design media may be subtle and significant, but perhaps under-utilized in the context of a design studio where they may not be all that reflectively handled even if intensively used.
   It is also possible that three-dimensional modeling in CAD displaces the three-dimensional thinking skill acquired through a more traditionally constructed application of descriptive geometry done by hand, thus creating a situation where the technology has become a middle man for that which students in a previous generation where expected to know more intimately. The under exercising of these three-dimensional visualization skills may be a step backward in design education. Yet, potentially, a different approach towards the use of three-dimensional modeling could perhaps help to enhance these skills.

3. **Design Computation:** In a matter of perhaps degree, it may be possible to distinguish the more deliberate and conscious harnessing of computer processes in this category from the less deliberate and hermeneutic harnessing of those computer processes in the previous case of “digital media”. For example, a design student may write a computer algorithm to generate a form in which complex geometrical relationships are calculated, and which may incorporate recursive or recurring spatial patterns or forms. Or, a design student may structure a feature tree of solid modeling software that enables the exploration of a particular set of optimized conditions or constraints, Alternatively a design student may setup a master component for possible variations of its instances in associative geometrical modeling such that each instance is more than a simple scale variation but contains other kinds of varying mathematically derived relations. In this category of design work, a rigorous and in-depth control over the generation of design form takes over from a less in depth methodology.
   In some cases, the same tool may have relatively less or more of a design computational application. For example, NURBS do not necessarily require a high degree of mathematical understanding by the designer to use. Perhaps a non-mathematically conscious trial and error approach would be characteristic of a productive but less in depth “digital media” use. Alternatively, given a firmer grasp of the underlying mathematical basis for NURBS, a designer can perhaps exploit them more effectively, a case for “design computation”. As another example, given any shape, a CNC set of tool paths may be achieved loosely by interpretative CAM software, a “digital media” approach. Or, CNC processes may be more directly programmed by the end user to yield tool paths more completely appropriate to the materials being processed, a “design computation” approach. Design computation uses are more demanding upon the design student’s knowledge of the computer and its underlying process. They may demand knowledge of higher level programming languages or at least script writing tools. This more deeply technological approach gets beyond use of conventional software as reflected in user-friendly menus and icons. It is an approach in which the software engine itself can be modified towards uses not intended by the original developer.

4. **Design Theory and Methods:** In this final category, the computer becomes a research vehicle for exploring the nature of design activity. This may take the form of observational experiments on its use or the testing of new design paradigms relative new experimental computer based design tools. It may in some schools of thought explore the nature of design cognitive processes by modeling them in algorithmic or simulated form. A similar body of theory may in different schools reflect different institutional biases. The development of new technology through this area of education and research may contribute to the ultimate commercial distribution of that technology itself, but the primary objective is not necessarily the development

of new technology or a design product, but rather insight into the nature of design.

Special degree programs in design and computation

A number of graduate schools of design recognize the significance of computer based design methods and research as constituting a specialized field with its own curricular requirements. This may include programs at a post-professional Master's degree level, Ph.D. or other doctoral degree programs. Students within these programs may do work in design, computer science, computer graphics, cognitive science, or in some other way combine coursework outside the more traditional range of design school subjects. Such programs may serve the interests of design professionals or those students with career paths that have a strong emphasis on research. While such programs have proliferated over the past fifteen years in many different countries (especially as reflects the authors' perspectives from North America, Europe, Asia and the Middle East), it is not clear the degree to which such programs individually may challenge the traditional boundaries of design research that has existed over a longer period of time or the degree to which there is a clear deliberate case being made for new kind of distinct academic discipline that extends the boundaries of a design education.

An argument for a distinct sub-discipline has in a sense been put on the table by the creation of the new special computer related degree programs, but it may be necessary to examine the presumption that these are new academic areas more closely. Do such programs reflect subtle divisions in the academic discipline or do they perhaps reflect temporarily shifting approaches to the higher education market? Making a case for or against these new programs is beyond the scope of this paper, but it could be argued that design theory and methods in relationship to design technology have a longer standing basis.

Divergent strategies in curricula tied to institutional approaches in design research.

At the core of any design program, undergraduate and graduate design studios and targeted computer related courses seem today to have become normalized in areas 1) and 2) above. That is, most if not all design schools expect general computer literacy applicable to course work in a broad range of subject areas. Also, at different levels of intensity, many courses now anticipate the use of "digital media" in the form of basic computer three-dimensional-modeling and image processing techniques. By the time that students advance to the upper levels of a design program, their ability to harness these techniques may grow in complexity with the nature of the design problems they may be expected to handle. For example, greater sophistication in geometrical modeling and analysis may go hand-in-hand with more articulate and tectonically advanced design problem solving in upper level courses and studios. Here, the most demanding use of conventionally available software may happen with students often pushing towards a commercial product's performance limitations. The menu of such courses may include both studio and advanced modeling and visualization courses, depending upon the nature of the institution, available faculty talent, and resources.

More abstractly and less widely in evidence, courses that engage design computation directly may posit a conceptually significant challenge to traditional design pedagogy. The symbolic and algorithmic processes of harnessing a computer can be engaged at a deeper level than that of using well-prepared commercial software. The possible opportunities of "computation" may be explored at the level of experimental software or hardware development. Any strong program in design is likely to engage more than one of these type courses, but this is not typical. In programs offering such programs, students may gain greater insight into the technology and its connections to design methods, and as a result may be best prepared to challenge the norms of its use in conventional practice. Such students may be well positioned to envision new uses or play of leadership role in defining the next generation of technology.

Finally, the design theory and methods subject areas seem well suited to advanced post-professional degree programs, where aspirations in design inquiry have a long standing tradition if only more recently made more widely visible since computers have entered on the scene as an investigative tool. There is perhaps some difference of opinion as to whether such areas of curricula may be fully encompassed as falling under the study of architecture, or if the engagement of other disciplines places this subject area in a distinct and non-traditional framework.

Whatever may be the institutional bias, some advanced theory based subject offerings would seem to be perquisite to any school presuming to provide a well-rounded and challenging view of computers relative to the design discipline.

Caveats, observations and conclusions

There has been an intentional avoidance here of championing a school of thought that may be reflective of a strongly held research program on computers and design, such as "shape grammars", "constraints", "precedent case study methods", or "design and cognition". Internal to any such school of thought, there is also a probable legacy of rival positions and arguments. For example, not all "shape grammarians" hold to the same tenets.

Moreover, there has been no attempt to define here a specific educational sequence or program that must be carried out by every institution presuming to offer a rich context for computer based design studies. The broad categorical distinctions above do not recognize all the important trends. For example, especially of interest are pragmatic inter-disciplinary connections increasingly common in advanced course work, such as the integration of digital terrain modeling, CAD three-dimensional modeling and GIS into one share model space. Further, the recasting of computer aided design (CAD) as building information management (BIM) by one leading commercial vendor (i.e., Bentley Systems) reflects a widely held intellectual position among those who teach using digital design tools, but the explicit naming poses a separate challenge to the identity and place of computers in the design disciplines.

Still, it seems necessary to acknowledge that the subject areas must move beyond acting as end users of commercially available software in order that schools be engaged substantively in shaping the direction of digital design technology. Students are impoverished by the blind use of the technology, such as by not exercising the three-dimensional thinking skills of descriptive geometry, unless their engagement goes beyond a superficial level. Here too, the means to that engagement may vary widely. In all cases, some deeper reflection on the nature of computation processes, such as might even be afforded by considering how a calculator works, may provide a much needed foundation over the sometimes superficial, gratuitous and flashy use of that technology. The ultimate condemnation of digital design media is for it to be perceived as a representational device, simply and solely. That it is seen in that way is itself a condemnation of the teaching of digital design.

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