**Architectural Toolkits**

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**Abstract.** *This paper examines how, when, why and why not architecture students today use widely available digital toolkits. It also compares and makes observations on the work and nature of both analog and digital tools. The setting for the inquiry is an architectural design studio where, with no specific mandate to use specific tools from the part of the instructors, students were let free to use whatever tools they could find to explore, develop and finally present their design solutions. The paper reflects and focuses on the success and effective use of digital tools by students who opted to use new digital toolkits.*

**Keywords:** Education; Pedagogy; Design Process; Digital Design Education.

**Background**

In one short burst of intense artistic progress, the curious artifacts developed during the Renaissance by Leonardo Da Vinci, Andrea Pozzo and Piero Della Francesca allowed these artists and others to produce brilliant innovative works. Further insight into their techniques and the evolution of their artistry reveals that their accomplishments were due, to a great extent, to a seismic shift in how they were able to develop new tools and their willingness to adapt and use them. Some 400 years later, students of architecture, like their Renaissance counterparts, have been overwhelmed by the challenges posed by the arrival of a new architectural digital toolkit.

**Process - Setting**

The setting for this paper is based on an intermediate level architectural design studio and a series of digital seminars taught at the College of Architecture and Planning at the University of Utah. Both courses ran independently. In other words, there was no formal communication between the instructors involved in the studio and digital seminars. Moreover, the design studio did not focus nor was structured to give preferential treatment to any particular toolset, analog or digital. In short, studio participants were absolutely free to use whatever toolkit or approach they felt appropriate or useful as long as it lead to viable successful architecture. It should also be noted that about half of the students in the studio chose on their own to enroll in digital seminars while the other half chose not to.

The digital seminars included instruction and experimentation using a variety of digital tools including basic extruder as well as solids modeling applications. Students also played with more complex surface and non-rational B-spline modelers. Experimental form generators based on Lindenmayer Systems, fractal generators, and blob modelers were also integrated in the coursework. On the visualization side, experimentation considered tectonic qualities as well as a variety of lighting approaches.
Rendering involved scanline techniques, Mental Ray, advanced ray-tracing, indirect illumination, contour rendering, photon mapping, exotic materials plus the use of a variety of commercially available rendering machines including Brazil Rio, Maxwell Render and others.

Process – Building Typology and Program

The studio involved architectural interventions in the historic core of Frankfurt, Germany. After a field trip that included a thorough site survey and subsequent visits to historic sites and well known contemporary architectural interventions in the region, a research phase followed covering precedents and sustainability aspects. Actual design work began at the master planning urban design scale. Teams of students were encouraged to first address different urban design and planning aspects due to the quite large area under investigation. One of the studio’s principal goals was to solicit diversification in the proposals. In other words, students were free to develop their own building typology programs for a chosen section of the large site. The building typologies included libraries, museums, residential and mixed-use projects, and a mixed use artist studio/housing project.

Process – Studio Operation

By and large, students were given the opportunity to use and appropriate whatever resources, approaches or techniques to develop their projects, communicate their processes, and finally present their work to a jury. The research and field trip documentation work utilized widely available desktop publishing applications and a given layout template to ensure high quality and continuity in the documentation of the overall studio work. The urban development process was initially based on a large scale laser cut urban model, a task undertaken by the entire studio group. Following the urban design modeling and testing phase, students proceeded to develop sketches and ‘rip and tear’ models. It was observed that at this point in time most students began to utilize basic 3D digital modelers to explore and validate their approaches. Some students combined the assignments in the digital seminars with their design development process. Once the design process entered a more intense phase it was noted that students shifted gears and began using more often digital tools. These actions were augmented and complemented by many digitally fabricated laser cut models. Due to the laser cutter two-dimensional mode of operation some students developed their model files from physical models, and plan and
elevation information. Another group developed three-dimensional digital models from the onset.

Process – Digital Seminars

The digital seminars were based on four different building typologies. Using these, students were exposed to a variety of applications as described above. The instructional process was not based on teaching software step-by-step. Instead, the pedagogy focused on digital actions such as transformations or generation of multi-component geometries. A key pedagogical aspect was to not get involved in obscure command manipulation. In its place, students were made aware of the many ways a particular task is handled by different applications. Special highlighting was also placed on a systematic methodical approach to the design process where no single task was given special attention and this implied that every task along the process was to be given equal amounts of time. Preliminary ideation, early idea processing, development of transformations, tectonic quality definition, lighting attributes and design, etc. were all given identical priority in the most holistic way possible.

Observations

Why some students opted to use or not to use digital tools

From the onset it became clear that not all students possessed the same digital skill level. There were enormous gaps. For the most part, this was due to: a) individual choice, b) previous educational experiences due to rigid college and high school curricula structures and c) lack of digital resources. Even after many years since the advent of digital tools, numerous students are still intimidated by the use of sophisticated modeling and visualization software. Furthermore, many students do not seem to be aware that in order to be digitally proficient one has to invest a significant amount of time and energy. This is a fact that is neglected by many schools, where the curriculum does not allow for the necessary time outlay. Another aspect that surfaced was a kind of skepticism that some participants had regarding the potential benefits of using digital technologies.

Within the schematic phase in the actual studio setting, the use of ordinary digital tools such as simple two and three-dimensional modelers, Photoshop,
plus drawing on a laser cutter, allowed students to explore spatial qualities, structural approaches, and building organization propositions that were quite successful. In most cases, this was accomplished through physical models and two-dimensional traditional as well as digital ‘sketches’ via very schematic CAD drawings and/or Photoshop collages. Due to the nature of many projects with simple geometries, this approach was appropriate and valuable. However, some students opted for more complex geometries. From the onset one particular student made use of sophisticated modeling applications to assist his design experimentation on the physical model and to describe and define his geometry in the most viable way possible. This student’s strategy consisted of switching back and forth between analog models and sophisticated digital modeling tools to experiment and communicate his ideas.

On the other hand, and due to a lack of confidence in her abilities to employ complex digital tools, another student struggled with highly curvaceous organic shapes, trying at first to come near the forms through traditional clay and wooden models. Predictably, this approach worked only to a point. At the end, she failed to prove the validity of the approach because she was unable to project the proposed organic geometry to validate architecturally the spatial proposition and qualities. Simply put, the organic shapes had to be clearly projected and defined in order to explain their complex geometry. Unfortunately this did not happen. However, this student very likely would have been able to express architecturally her ideas if she had had enough time to thoroughly get acquainted with sophisticated modeling tools that allow users to project unto planes complex spatial geometric arrangements.

**What were the tools that were used more often and/or more successfully, and how were those tools applied**

The most successful students in the studio were those who were able to employ a full assortment of traditional and digital tools, blending physical models and sketches with three-dimensional digital tools.
models to further develop their designs. A key factor here was to use the appropriate tool for the right task in a time-efficient manner. During the initial master-planning phase, many students used the physical urban model and traditional sketching methods to determine their careful interventions, at times supported by simple 3D modeling software to analyze and document building masses. The common site model was produced as a group effort by all participants via existing two-dimensional digital files and the students’ photographic surveys. This digital model was horizontally sliced and sent electronically to the laser cutter. The process resulted in many wooden layers that at the end were simply glued together. It should be noted that there were problems with the model’s fabrication process because students misused the laser cutter by assembling the model using numerous layers of 6 mm MDF boards. This decision resulted in a tedious finishing process that demanded that the blackened edges of the wood be sanded thus negating the precision of the manufactured parts. Students learned that it is better to assemble an urban mass model from solid pieces of wood or some other solid material using traditional shop tools. Although these experiences were extensively discussed in the studio, similar mistakes were repeated in later phases of individual studio projects.

Throughout the successive building design development phases, two distinct groups of participants came into being:

a) One group used both analog and digital methods splitting the techniques for the most part in an evenly manner. Most students developed their schemes via simple digital modelers such as SketchUp. They then used a laser cutter to assemble physical models. This process was assisted by two-dimensional AutoCAD drawings that were often projected from the digital three-dimensional model. The process was augmented by traditional sketches to validate spatial qualities and to communicate special architectural design intentions. According to comments made by jurors and instructors design quality was high in this group. It was noted that in previous studios most students had already developed similar successful strategies to approach and tackle design tasks. In some cases, the physical model was the tool of choice. Conversely, other students opted to use SketchUp models to explore their schemes. In most cases all were able to test their propositions in subsequent steps through fast physical ‘rip-and-tear’ or more sophisticated laser cut models. Those students who were able to alternate back and forth between these different techniques and scales many times developed the most successful architectural schemes, due to the level of exploration and control they had along their process.

b) After a brief initial experimentation period with physical models, the second group chose to experiment with digital technologies as described earlier in this paper. Their schemes were different from the first group in that the geometries being investigated were clearly more complex. Some picked solid modeling, others chose surface modelers. Some even played with experimental form generators.

Figure 4
Tedious finishing process on an urban model that is produced from laser-cut MDF-layers.
The group also toyed with refined animation tools to present their project throughout the semester. At this point it should be noted that for the most part this second group demonstrated that they were able to design and develop projects successfully with a digital toolset only. And, most importantly, for both groups, success was determined by the individual student’s commitment toward their design process. As for the second group, such vow was already high due to the nature of the complex modeling and animation tools the group had been utilizing. It should also be noted that the students who took the digital path took a much higher risk in their project development since they were generally not used to this kind of process. They too had to develop new strategies to employ the tools and the process that comes with them. At the end, all projects coming from this second group were also deemed successful.

**Significant items and comparisons observed during the ideation process**

Traditionally, designers have interacted with design media through ‘conversation with materials of a situation’ (Schon, 1983). The traditional materials include sketches on tracing paper, design drawings, physical modeling materials, and tangible models, which are used in a conversational process. When one uses digital tools the process involves a human-to-computer interface for the transformation process. To have a desired ‘digital conversation’ with materials of a situation, the user is on the one hand foremost involved in a process of conversation with the computer code, or the application. On the other hand, the unique configuration of a specific design problem can be addressed much better in reoccurring cycles by reflecting upon effects of earlier moves in order to make new moves, because the computer, especially when it is coupled with a digital model making process,

*Figure 5*
Form, tectonic, and spatial exploration through the physical model
allows for fast production of a high number of elements, therefore supporting the conversational process. This particular aspect was strongly encouraged in both studios and seminars.

The most successful students in both groups were those who embraced several tools and forms of spatial representation during their ideation process, and thus were able to investigate their projects through many layers of exploration. This was reflected in the architectural quality of the emerging projects. The digerati participants were able to employ the full range of available tools, due to a strong support through what was being explored in the digital seminars. These students focusing primarily on the advanced digital toolset in their design development process had a slight disadvantage over the students that were using familiar tools. As they quickly found out, they had to invest more time in getting acquainted with the advanced digital toolset. Furthermore, they also discovered that they also needed more time to develop their architecture due to the complexity of their chosen geometric forms. On the other hand, they were able to come up with a reasonable amount of experimentation, sometimes ending with some unexpected startling result in their ideation process. Simply put, it became obvious that the second group was taking more risks in their design solutions in terms of architectural vocabulary.

The students who used the physical model primarily for their development process did rely on a proven method to explore space as mentioned above. Most used geometries that were easily manageable with traditional tools and the laser cutter.

Finally, those participants who limited themselves to traditional tools and methods seemed to have developed solutions that were deemed not as powerful or intense relative to the rest. Their schemes coming out of their ideation process were clearly limited by their narrower toolset. This condition was aggravated by limited skills using traditional tools namely model making, hand drawing and sketching. Further, their final presentations were not up to par even though they employed rather clumsily some digital tools. Their use of digital tools was restricted to presentation devices. They did not use the digital toolkit to explore and/or experiment with new architectural spatial opportunities.

Significant issues and comparisons observed during the presentation process
As expected, the final presentation concluded in a smorgasbord. Projects were juried. Ranges and qualities varied immensely. Among the more significant notes expressed by the jurors:

1. While not necessarily implying better architectural quality, it was quite clear that the digerati students were able to: a) develop their schemes further, b) develop geometries that were generally more complex, c) visualize solutions with higher quality standards.

Figure 6
Exploration in the digital seminars.
2. Based on the limited student sample which included students with the same educational background, the digerati students were able to present, within the rather limited amount time given to execute the project, a more thorough and convincing final presentation.

3. Students using traditional presentation schemes verbally expressed that they wished they had invested more time and energies learning the use of digital technologies.

**Conclusions**

The digital toolkit is an ever-changing apparatus. Studying how students of architecture today approach this apparatus is critical because of its elusive nature. Today, many of us involved in digital production know how to build and operate familiar kinds of digital systems. However, the idea of inventing new kinds of uses for these systems has not occurred. This is why we need to develop a new attitude about digital architectural production, starting with architectural education. Only by understanding how each separate component of the digital education process works and is interpreted by its users, we can modify them and combine them in different ways to improve existing educational approaches or solutions no one has ever seen before, and to experience accidental discoveries that often open our eyes toward something unexpected and new. To be able to do so, we have to allow students more time for the exploration of those tools; we have to aim toward a natural and consistent employment in the design process, using the digital toolset to support traditional tools that still have validity.

**References**


*Figure 7*
Sample images of projects.