Architectural Design Studio:
Digital and Traditional

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Abstract: The nature of the task of representing architecture alters to reflect the state of architecture at each period of time. In simulating architecture, the necessary conversion from that which is inhabitable, experiential, functional, and at times, indescribable to an abstraction in an entirely different media is often an imperfect procedure that centers on its translation rather than the actual design. The objective in visualizing any architectural design is to achieve a situational awareness that allows for meaningful criticism of the design. Computer-aided three-dimensional (3D) visualization technology has made available new representation techniques. Surpassing the traditional means of graphic illustration and scaled models, this technology has been primarily developed to decrease the amount of abstraction between architecture and its documentation. The general objective of this paper is to present a study carried out over the last six years in which the progress of students in a traditional studio was compared to the progress of similar students in a digital studio. We have assessed the effects of the tools over the six-year period (24 different projects) by evaluating solution-generation in trial-and-error process and learning problem-solving strategies based on the Cognitive Flexibility Theory paradigm. Students using the digital studio were found to generate more and various solutions consistently.

Introduction

The general objective of this paper is to present a study carried out over the last five years in which the progress of students in a traditional studio was compared to the progress of similar students in a digital studio. During the last five years a component of our second-year design studio introduced students to the use of computers to enable them to enhance their design projects and increase the number of design alternatives they generated. Students spent one-half of one semester using computers to design their projects as part of the normal rotation through the different instructors. The projects were not specific to the digital studio: the assignments were the same as for the traditional studio. Integration of computers directly into the design studio took place in a physical environment that united the traditional drafting table with the computer. The effects of the digital studio over the five-year period (20 different projects) have been established by evaluating solution-generation based on Cognitive Flexibility Theory. Students using the digital studio were consistently found to generate a greater number of solutions.

Through the use of digital design media, 3D modeling and imaging, students in the digital studio developed a critical design sense of fundamental architectural forms, systems, and vocabularies. They examined the relationship between order and idea and developed their analytical and design capabilities through this exploration of digital technology.

General Problems in Design Education

The objective of representation in any architectural design is to achieve a situational awareness that allows for meaningful criticism of the design. The more abstract the design representation, the more difficult it is to attain this awareness. To a competent architect, the summation of the information drawn on plans, specifications, or other design documents provides the information necessary to formulate an approximation of the design project. The architect's ability to comprehend and extrapolate information is acquired through years of education and working experience. Architecture students are placed in the difficult position of attempting to understand complex drafting conventions without the benefit of years of experience.

Despite its importance, understanding and visualizing space is one of the most difficult skills that design students must acquire during their education. Most design students begin their education with very limited personal experience in observing and understanding the spaces and forms that they are familiar with on an everyday basis. Architecture forms a backdrop against which their activities take place, but they are not consciously aware of the influence that the design of those spaces has on their perceptions. Students must learn to experience the world as an observer and participant, aware of light, form, proportion, scale, color, and texture, as well as the perceptual feeling that they create. On a broader scale they must learn to see and experience spaces and forms in a way that will enable them to understand not only the visual, but also the environmental, cultural, and social aspects of the natural and built environment around them.

Another difficulty students face in understanding and visualizing space is the limitations of the media used to represent and manipulate space throughout the design process. Drawing by hand continues to be the central activity in the design process despite the rapid advances in computer graphics. Through the use of manual graphics—pencil, marker, watercolor, airbrush, etc.—a design student is taught to translate a mental picture onto the drawing board. This type of visualization technique is generally accepted as an effective design tool that has little impact on the appearance of design form. All too often, however, graphic methods for representing space and form have no relationship to any visual experience, but are merely a 'drawing-board style.' Unfortunately stylized techniques can be copied by students with a high degree of sophistication. Emulation of style by students can result in a graphic vocabulary that is more concerned with technique than any experiential understanding of space. [Radf90]

Even when used in an appropriate way, traditional graphic media have another limitation: they are static images, which cannot represent the effects of movement and time in terms of light and motion. Because our perceived experience of architecture is primarily a sensual event involving movement and change over time, a two-dimensional static image is inadequate as it can only express the quality of a space at one point in time and from one point of view. Visualization that includes movement and time sequence allows the designer to make better judgments about space and form, as well as to see the effects of light, color, texture, reflectivity, and contrast. Lifelike simulations give the opportunity to experience mistakes before they are constructed, and to learn from them.

Digital Design, Conceptual Complexity, and Flexible Learning

New representation techniques, made possible by the new computer-aided 3D software packages, surpass the traditional means of graphic illustration and scaled models. This technology has been primarily developed to decrease the amount of abstraction between architecture and its documentation. In addition to 3D representation, this new technology offers previously unattainable qualities such as motion, texture, real-time shadows, and so on, in order to further enhance situational awareness.

Computer-aided 3D visualization in architecture deals essentially with volume conceptualization. Traditional 2D architectural representation is capable only of depicting aerial or planar concepts and implies a spatial dimension only when these concepts are used in series. By merging motion with computer-aided 3D visualization techniques, spatial concepts can be easily conveyed. Such spatial information, when delivered through proper apparatus, can simulate depth—one of the most important components of spatial cognition. In addition, other architecturally related concepts such as shadow studies, transparent underlays, and form morphing, which were generally unavailable through traditional drawings, can now be represented in a manner easily understood by students. Within the architectural context, 3D visualization techniques involving depth perception can convey relevant information to students more efficiently and flexibly with less misrepresentation than traditional techniques.

The ill-structured nature of the problems of architectural design makes the introduction of computers particularly appropriate early in the design education process. The ill-structured nature of architecture, discussed by various authors (see especially [Simo73]), basically results from the fact that each attempt to find a satisfying solution is a product of the simultaneous interaction of several domains of knowledge, each of which is individually complex. Furthermore, even in design problems which are nominally of the same type (e.g. urban in-fill, addition to existing structures, etc.), the interaction of the knowledge domains varies considerably, adding to the ill-structured nature of the architectural problem solution.

Characteristics of ill-structured domains create serious problems in the attainment of learning goals, such as the mastery of conceptual complexity and the ability to independently use knowledge gained through instruction in new situations that differ from the conditions of initial instruction. Spiro et al. [Spir91] in a discussion of Cognitive Flexibility Theory suggest that these problems "can be overcome by shifting from a constructive orientation that emphasizes the retrieval from memory of intact preexisting knowledge to an alternative constructivist stance which stresses the flexible reassembly of preexisting knowledge to adaptively fit the needs of a new situation." In an argument particularly relevant to architectural education they go on to state that conceptual complexities and cross-case inconsistencies in ill-structured knowledge domains cause the employment of precompiled schema to be inadequate and inappropriate. They suggest that because knowledge has to be utilized in so many different ways that it is impossible for all of them to be anticipated in advance, and that emphasis should be shifted from the retrieval of intact knowledge packages to the construction of new understanding. Instead of retrieving from memory a previously structured recipe for how to think and act, an appropriate ensemble of information, from various knowledge sources, suited to the particular understanding or problem-solving needs of the situation at hand, must be produced. As Spiro et al. [Spir91] point out, this is because many areas of knowledge have too diverse a pattern of use for single prescriptions, stored in advance, to cover enough of the cases that must be addressed. (For other discussions of issues related to cognitive flexibility see Duffy and Jonassen, [Duff92].)

Central to Cognitive Flexibility Theory is the idea that revisiting material at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives is essential for acquiring a thorough command of all ill-structured knowledge domains. Because of the complexity of case and concept, multiple explorations must be made to grasp the variability and interconnections of knowledge. As Spiro et al. state "Some of the representational perspectives necessary for understanding will be grasped on a first or second exploration, while others will be missed until further explorations are undertaken. Some useful connections to other instructed material will be noticed and others missed on a single pass (with connections to non-adjacently presented information particularly likely to be missed)." Revisiting material leads to new insights and mastery of the different ways that the architectural knowledge can be utilized. Instruction should prepare students for the diversity of uses of architectural knowledge, while at the same time demonstrating patterns of interconnections and the context dependence of that knowledge. Students must learn a repertoire of flexible knowledge that can be used in constructing understanding of future cases of knowledge application. Multiple, alternative solutions to problems increase the understanding of the knowledge domain.

Spiro and his colleagues suggest that computers provide an effective strategy for acquiring and flexibly utilizing knowledge in ill-structured knowledge domains. Cognitive Flexibility Theory deals not only with the flexible use of preexisting knowledge but also with the acquisition and representation of that knowledge. Acquisition, flexible use, and representation of design knowledge are the key elements in architectural education.

Second-Year Design Studio Education

The second year of design studio education is critical in students' training as it introduces significant issues that the students must address in subsequent studios. The second year builds upon the knowledge, skills, and enthusiasm that students bring with them from the first year, where they have acquired basic drawing and modeling skills and have been taught to think in spatial terms. In our program, the second-year studio must form a bridge between the abstract design principles and ideas taught in the first year and the synthesis of a building that is the focus of the third year. In the second year, design problems are formulated to instill an awareness of the impact of space and form, as well as place-making, use, and tectonics on architecture. Students must learn to use their knowledge in a flexible manner, producing multiple alternatives to design problems.

During the second year, it is essential to develop the students' ability to communicate graphically and model productively in order to consolidate the knowledge that they have acquired during the first year. It is imperative to instill basic skills that are related to perception and visualization of materiality so that the students acquire a solid foundation of general knowledge. In our studio we make a conscious effort to integrate visual communication with the design process. Drawing and modeling, both with traditional techniques and with computer software, constitute the basis of studio performance. Students are encouraged to view architectural drawing, including computer-aided drawing, as a valuable process of thought and experimentation. Students are presented with problems that emphasize the analytic and synthetic activities of the design process and they are urged to show a concern for all levels of work, from the contextual implications to the smallest detail. It is important that they learn the complex nature of the interactions of the different areas of architectural knowledge.

The first two years of architectural education are the most crucial for architecture students because during these years students form attitudes that they carry with them throughout their careers. During this time students struggle with the concept of architecture as a hybrid of art and technology. The students' preconceptions about the nature of architecture is challenged by the introduction of new ideas about the physical world; therefore, it is appropriate to introduce innovative computer representation techniques as early as possible in design education so that they become an integral part of the process of the making architecture.

Computing in Second-Year Design Studio

Over the last ten semesters (twenty design rotations of seven-and-a-half weeks each), a component of our second-year design studio introduced students to the use of computers in enhancing design possibilities. Students spent one-half of one semester using computers to design their projects as part of the normal rotation through four different instructors. The projects were not specific to the fifteen-student computer studio: they were the same assignments as for the other three sections of second-year. The students were ranked according to their cognitive abilities and their performance in the previous year and assigned in a matching process to the traditional and digital studios. This program involved 259 students during the ten semesters. Integration of computers directly into the design studio took place in a physical environment that united the traditional drafting table with the computer. All students were assigned their own workstation as part of their drafting table. The program of instruction for the digital design studio followed eight basic steps. To begin students made observations of relevant artifacts, then they generated interpretive constructs, both physical and virtual. Next they contextualized the problem and collaborated in observation, interpretation, and contextualization, thus creating multiple manifestations. The final stage was evaluation. This cycle was repeated until the conclusion of the session. Students used digital design media, and 3D modeling to develop a critical design sense of the fundamentals of architectural form, systems, and vocabularies.Examples of student work produced by our second-year design studio using digital technology illustrate the success of this studio. (See Figures at end.) The projects involved a consistent reduction of site constraints and were defined in a sequence—from a constrained site and limited set of inquiries to a less restrictive site and open-ended set of questions. The first problem, an inner-city row house, dealt with an infill site within a consistent urban fabric, raising issues of the presence of the building within the inclusive entity of the neighborhood, one of the diverse components of the city. The last problem, a winery, placed a series of self-generated objects within a landscape. The interim two projects related urban qualities with landscape architecture in inverse proportions, allowing the interaction between the two to inform and enrich each other. The second project, an addition to a classroom building, enclosed a garden or courtyard within an urban construct, while the third, a performance art gallery, placed a building as a fragment of a larger composition that defined a public green space. Each of these projects also addressed certain thematic and programmatic concerns as determined by the specifics of the project. Thematic cohesiveness as well as organization of spaces and concepts were necessary for a successful project.

Before they enter the studio students have very limited experience with software modeling packages. During the first week of the project, as the students are developing their conceptual ideas for the design, we begin to familiarize them with the computer through a series of small exercises. We do not attempt to teach them everything the particular package we are using is capable of, but rather to give them the basic ideas that they need to start the project and instill a sense of the possibilities of the package. As they explore their ideas about the building, they explore the potentials of the 3D synthesizer software.

The faculty for the second-year design studio has been fairly consistent over the last ten semesters. I have taught the digital design studio and the same two instructors have taught two traditional studios. Only one of the traditional studios has had a variety of instructors. For every semester students in the digital design studio have consistently produced a greater number of alternative design solutions (see Table 1). On average they generated 38 per cent more alternatives than the students in the three traditional studios. Of course, in the traditional studio environment some instructors are better at encouraging more alternative design solutions. An example of this difference is the professor for Studio One. The students in that studio consistently produce more alternative solutions and they perceive this difference as having a positive effect on their learning. Students in the digital design studio produce 28 per cent more design alternatives that the traditional studio with the highest number of alternatives. Their assessment of the positive impact of a larger number of alternatives is reflected in the student evaluations, and this is reinforced by the results of the faculty crits.

There are some problems that have arisen that have to do with the fundamental nature of the computer and its impact on the design process. These problems can be overcome if they are understood and anticipated by the studio instructor. The main problem has to do with the repetitive efficiency of the computer. Some students are tempted to use the computer's ability to create exact replications of design elements to increase the complexity of their representation. The solution may become more complex visually but does not become a better solution. In these cases the computer can actually impede the design process. Talented students use the computer to simulate the 3D qualities of the space in their model of the proposed artifact. Powerful visualization tools do not guarantee a better understanding of space or better designs. In fact, they may increase the potential, for students in particular, to become more concerned with creating flashy models and animations than with the experiential qualities of the space that they are designing. Computer-based modeling will allow good students to produce better designs; it will not turn bad students into good designers.

Number of Students	Traditional Studio One		Traditional Studio Two *		Traditional Studio Three		Digital Studio	

Number of Alternative Design Solutions

24	2.45	2.30	2.00	2.21	1.95	1.95	2.95	3.05
30	2.50	2.55	2.15	2.14	2.00	2.05	3.05	3.10
25	2.40	2.45	2.20	2.25	2.05	1.95	2.95	3.05

20	2.55	2.40	2.15	2.05	2.15	2.10	2.90	3.00
25	2.40	2.25	2.10	2.05	1.95	2.05	3.05	3.15
26	2.35	2.20	2.12	2.00	2.15	2.20	2.95	3.25
28	2.50	2.45	2.25	2.25	2.05	2.10	2.90	3.00
25	2.15	2.15	2.25	2.20	1.95	2.15	3.00	3.20
26	2.40	2.30	2.34	2.35	2.10	2.25	3.05	2.95
25	2.30	2.45	2.05	2.05	2.05	2.05	3.15	3.05
Average	2.38		2.16		2.07		3.04	
Average	2.20						3.04	

* only Studio Two had a variety of instructors.

Table 1. Number of alternative design solution produced by students.

Conclusions

Cognitive Flexibility Theory suggests that in order to master ill-structured knowledge domains, such as architecture, students must revisit material and reutilize it in multiple ways. The more times students flexibly use their knowledge, the better their acquisition and comprehension of that knowledge. I have found that the use of computers in studio instruction increases the number of alternative solutions to design problems that students are able to produce, thus suggesting an increased mastery of material. Initially we had introduced computers to students using a special course in which projects were tailored to computer use. This approach had moderate success compared to the results that we achieved when we introduced computers directly into the mainstream studio. Instead of fitting the project to the computer, as if only very special projects would be appropriate for using the computer, we introduced it to the students as another, very powerful, tool at their disposal. Our digital design studio has been successful in encouraging the acquisition of design knowledge by students. It has enhanced the flexible use of that knowledge by stimulating an increased number of representations. Critiques of student work indicate that not only do students propose more solutions to the problems, but that these solutions are of higher quality, reflecting the increased awareness of the complex nature of architectural knowledge.

References

[Duff92] DUFFY, T.M. and JONASSEN, D.H., *Constructivism and the Technology of Instruction: A Conversation,* Hillsdale, NJ:LEA, 1992

[Radf90] RADFORD, A.D. and STEVENS, G., "Role Playing in Education: A Case Study from Architectural Computing," in: *Journal of Architectural Education,* 42(1):18-23, 1990.

[Simo73] SIMON, H.A., "Structure of Ill-structured Problems," in: *Artificial Intelligence*, 4 1181, 201, 1973.

[Spir91] SPIRO, Rand J., FELTOVICH, Paul J., JACOBSON, Michael and COULSON, Richard L., "Cognitive Flexibility, Constructivism, and Hypertext: Random Access Instruction for Advanced Knowledge Acquisition in Ill-Structured Domains," in: *Educational Technology*, Vol 31, num 5, pp 24-33, May 1991.

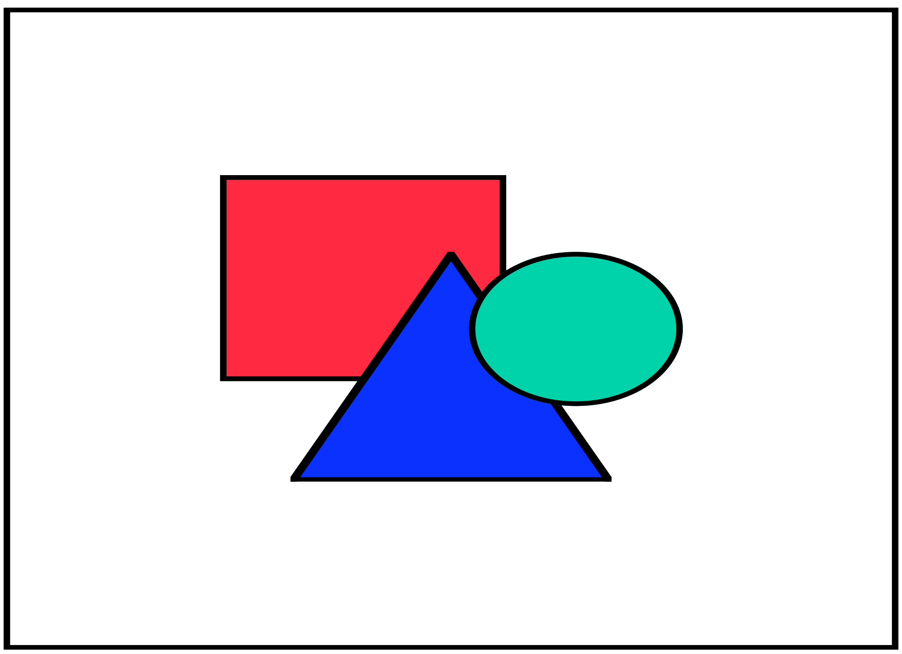

Figure 1. Convention Center

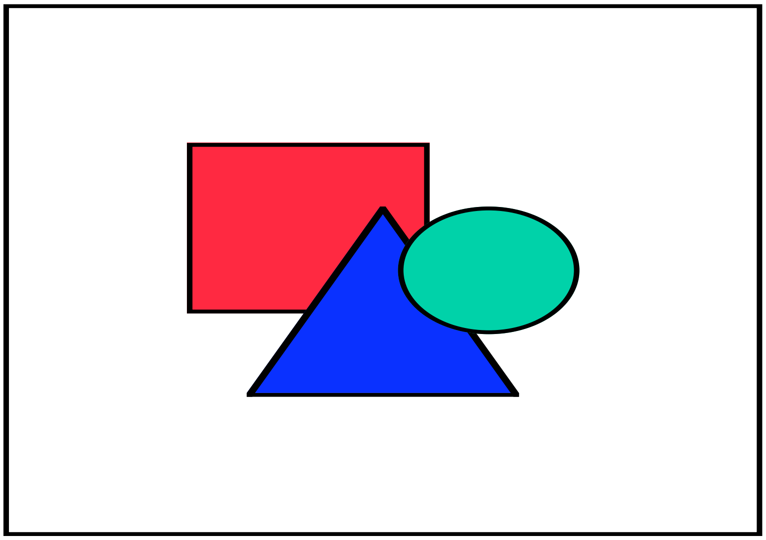

Figure 2. Factory

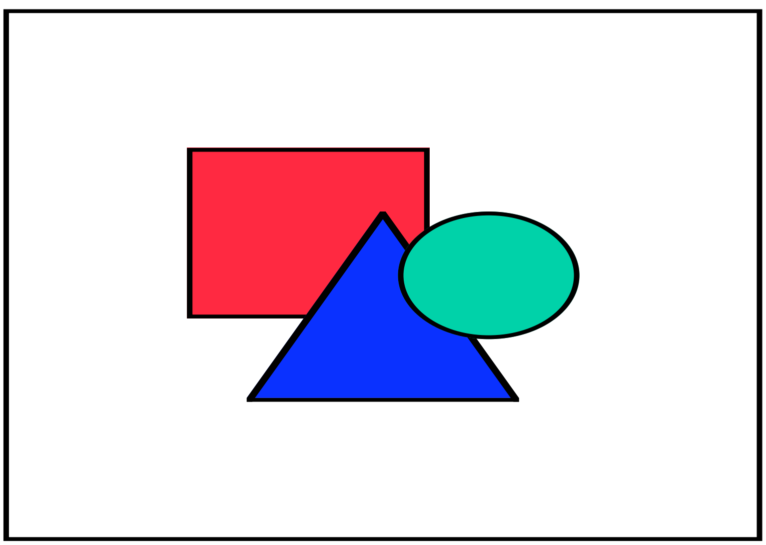

Figure 3. Chemistry Building

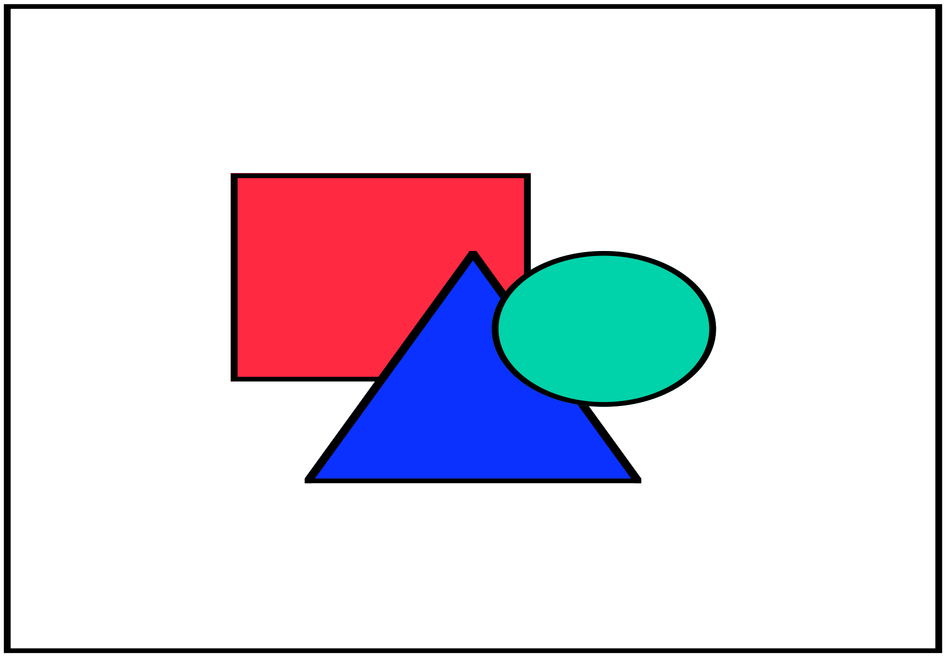

Figure 4. Apartment Building

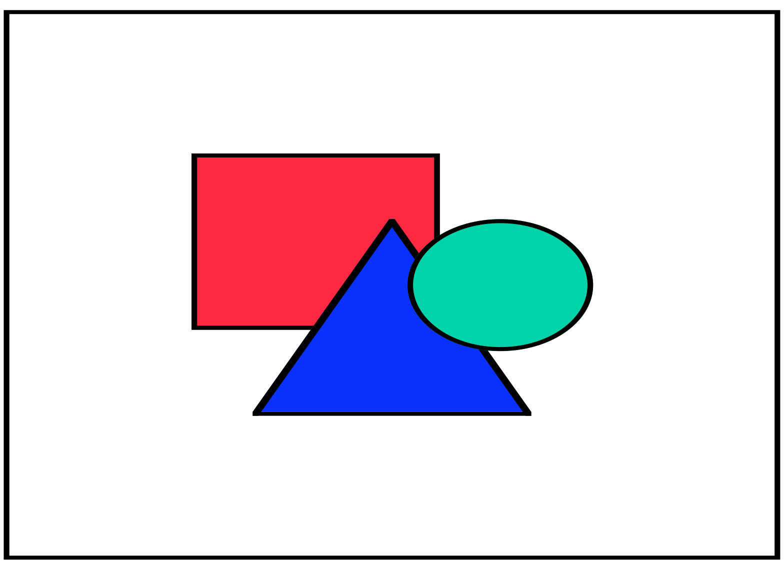

Figure 5. Library

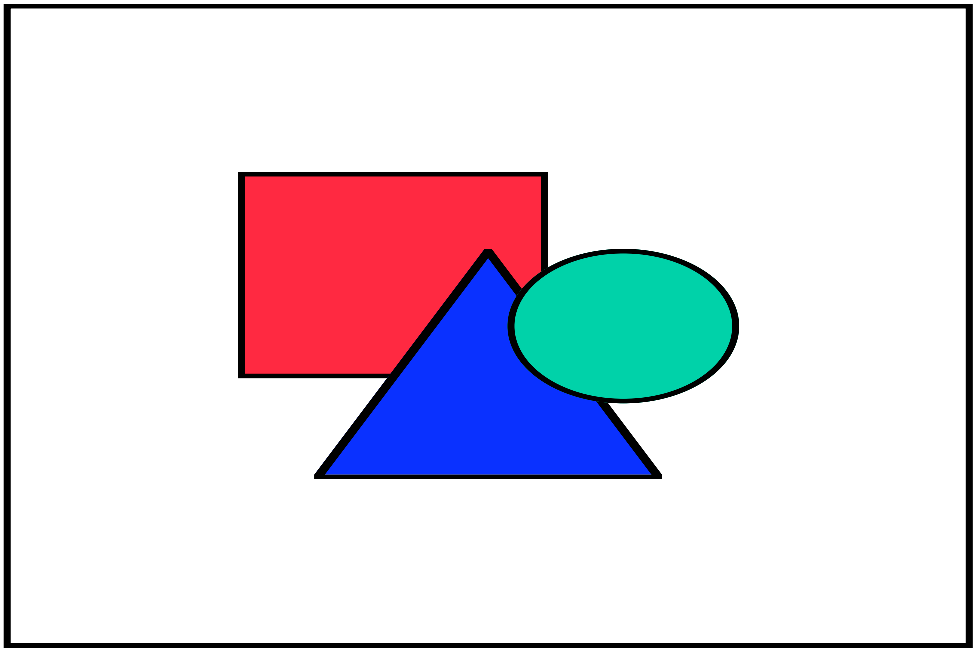

Figure 6. Construction Yard