Measuring the Difference: The Impact of Media as a Technological Tool on Architectural Design

OSMAN ATAMAN
Temple University

INTRODUCTION

In architecture, media is defined as apparatus for selecting, gathering, organizing, storing, and conveying knowledge in representational forms. More specifically, media is a tool or a combination of tools that are used to create graphic representations such as drawings, images and models. From a theoretical viewpoint, media can be regarded as an important and influential factor in the design process. Consequently, the potential for a relationship between media and architectural design can be seen when the interaction between cognitive processes and characteristics of the environment is considered (Kozma, 1993; Salomon, 1993; Salomon, Perkins, and Globerson, 1991) Given this, it would be appropriate to assert that the nature and power of the available media facilitates what is conceived and accomplished. In the generation of new ideas, the media can be regarded as a tool of primary importance. Conversely, limitations in the design can result from the limitations of the media. In this respect, media can be thought of as cognitive tools that serve constructive thinking, transcend cognitive limitations, and engage in cognitive operations not capable otherwise (Pea, 1985)

The general agreement among architects, architectural educators, and researchers is that new technologies—digital media in particular—will play a critical role in the future of the profession. But, a debate rages about how architects should be trained to interact with these media. We do not have a clear answer to this issue. The problem is that there is not even an established relationship between media and architectural design. The primary reason is not the lack of this relationship but the lack of empirical studies. As a result, our understanding of media is fuzzy and unclear. Perhaps, this is partly due to the lack of adequate systematic research, and partly due to difficulties in formulating essential questions. Moreover, existing arguments are often based on implicit conjectures, and these may block the formulation of productive research questions. Consequently, there have been many speculative claims that students or junior architects, who cannot draw freely and thus design only within the limits of their power of representation, are the victims of analog take-over (Heath, 1984). Hence, media is a constraint on design thinking. In fact, many authors have made assertions and predictions that the capabilities and limitations of the media have a direct effect on the outcome of the design.

In order to test these claims and to provide a framework for their potential contributions to architectural education, this study aims to study media and its' effects on architectural design, particularly architectonics. It focuses on a specific level of architectural education, two types of media and the ways they relate to major aspects of design, such as space-making and form-building. It provides an opportunity to compare the effects of different media and consequently to establish a link between media and design.

One of the main assumptions of this study is that in architecture, media in general, and digital media in particular, are cognitive tools that affect design and mediate design thinking. There is a relationship between the media a designer uses, and the cognitive processes he employs. This assumption is based on media theory, advocated by Kozma and Salomon (Kozma, 1993; Salomon, 1993; Salomon, Perkins, and Globerson, 1991). According to this theory, there is a causal relationship between media and cognitive processes, and that this relationship influences learning. They argue that thinking is activated by learning activities, and learning activities are mediated by instructional interventions, including media. Researchers have shown that there is a reciprocal interaction between the media and aspects of the external environment (Greeno, 1988; Pea, 1993; Perkins, 1993; Salomon, 1993) and this interaction is strongly influenced by the extent to which internal and external resources are combined. Even though Kozma's media theory specifically refers to learning in general, the assumptions he and later Salomon have made are worth applying to architectural design.

In order to utilize this theory within the limited context of architectural design, this study first employs quasi-experimental design and later conducts a comparative study that may suggest some answers to the theoretical as well as practical issues that are discussed in this investigation.

RESEARCH DESIGN

During 1996-97, a total of 90 students who were enrolled in a first year design studio at Georgia Institute of Technology participated this study. Some of these same students were also enrolled in an introduction to computing class during the same time. The experimental group consisted of the students who took the design studio and computer course together (Group 1). The control group consisted of design studio students not enrolled in the computer class (Group 2). Both groups worked on the same design project. Group 1 used digital media while Group 2 used manual media. Digital media included computers with hardware and software (drafting, modeling, rendering, animation). Manual media included traditional drafting tools such drafting board, T-square, parallel bar, scale, pencil, paper, etc. and physical model making tools such as cutting boards, x-acto, foam core, chipboard, wood, etc.). Any students registered only to the computer course were excluded from the sample, as were students who had taken the studio previously. Through an informal preliminary survey, two groups appeared to be equivalent in terms of education and knowledge level except that the experimental group was exposed to the independent variable "Digital media" and the control group was not.

Because of factors influencing the sample and other experimental conditions, a quasi-experimental research design was used. The independent variable and the dependent variable of this study were "media" (both digital and manual) and "design" respectively.

PROCEDURE

All students were given the same instructions and treatment. Overall, all students had to meet certain procedural requirements for the course and follow the same schedule. The same instructors (both main instructors and teaching assistants) taught all studio sessions. Likewise, the same instructors taught the computer classes. All studio students were given the same lectures and they all had to go through group pin-up and discussion of alternate schemes, revisions, and partial design evaluations. Even the pin-up groups were distributed randomly by including both digital and manual media users. The final requirements were exactly the same. The only differences were the media they employed and some presentation requirements were optional for the digital group.

MEASUREMENTS

Relevant conceptual and operational definitions of the first year architectonic design issues related to this study are identified. Since the assessment of architectural design is difficult, a set of quantitative measures is developed in order to lay out the procedures that provide criteria for the evaluation of students' projects and allow for a quantitative assessment of the differences between the two samples to be made.

Two levels of measurements were taken in this study: Quantitative and Qualitative. Quantitative measures intended to measure aspects such as categories, numbers, degrees, proportions, size, location, etc., and qualitative measures intended to measure as designers' subjective evaluations of a project based on several survey questions. In terms of statistical data types, both categorical and continuous data types were used for quantifiable aspects of design, and numerical types for the qualitative aspects of design.

RESULTS AND DISCUSSION

Concept Development

In all analyzed conceptual categories (parti, spatial organizations, and ordering systems), it was found that unclear conceptualizations were more likely to appear in the manual media group regardless of the sequence of the concepts they employed. During the assessment, a new "Unclear" category needed to be added to classify unidentified concepts. This new category accounted for a large share of the manual media groups' design conceptualization analyses. Over one fifth of the manual media group projects were evaluated as inappropriate for one of the pre-defined concept categories. For example, in "Spatial Organizations" 34 percent, likewise in "Ordering Systems" 24 percent and in "Parti" 18 percent of the manual media group's projects were labeled as "unclear." Meanwhile, the "unclear" category in the digital media group was 2 percent on average.

Another important finding of the concept development analysis that would appear to be effected by the media was the variation of the samples. The manual media group seemed to produce some easy-to-build concepts and created fewer categories. For example, in developing "parti", the manual media users distributed their designs among two major categories (Tri-Zone with 40 percent and Bi-Zone with 16 percent). In "spatial organizations" and "ordering systems" the manual media group used three major categories whereas the digital media users distributed their designs more homogeneously over various categories.

Furthermore, the resulting conceptual implementations by this group tended to be less complex and more ambiguous and displayed fewer features than the digital media group. The digital media group appeared to overcome this problem. These results indicated that from the manual media users' point of view, there was simply not enough flexibility and/or sufficient time to develop and explore a wide range of alternatives and refinements. This kind of exploration and efficient conceptual representation of content is essential for effective concept development. Moreover, it seemed that certain conceptual issues were related to some specific capabilities of a particular media. For example, the extensive use of grid organizations in the digital group projects can be explained with the constraint and snapping capabilities of digital media. Manual media can handle only a restricted formal movement with limited efficiency to allow conceptual design exploration.

These results suggest that the employment and utilization of digital media gave students enough flexibility to study, to

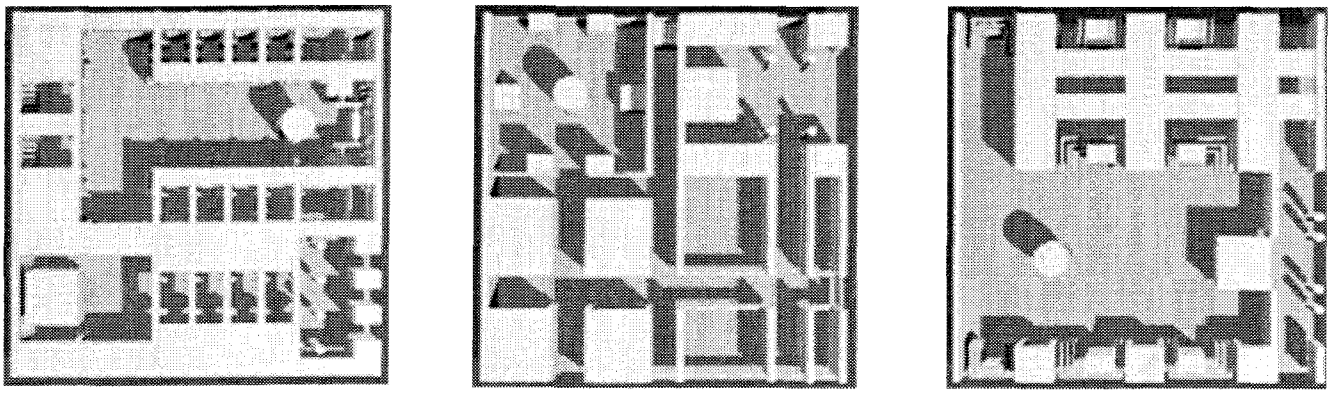

Figure 1: Sequential conceptual developments in digital media projects

execute and to maintain desired or expected concepts. The relatively more homogeneous distribution of design concepts in all concept categories and the clarity and readability of these concepts in the digital media group's projects were supported with the consistency of the sequential concept developments. The main problem with the manual media group's projects appeared to be the difficulty in manipulating these issues. One explanation is the cross-examination of these conceptual principles after their development. For example, once manual media students decided their parti types and started using organizational principles, their initial partis either collapsed or lost their specificity. Therefore, a large number of unclassifiable, unclear concepts were seen mainly in the manual media group's projects. This problem was also related to the lack of consistency among conceptual stages. According to the cross-comparative analysis results, the digital media group exhibited more sequentially consistent concept developments than the manual group. The measured relationships were mostly consistent in the digital media group projects whereas there were several inconsistencies in the manual group projects. For example, in the digital group projects certain sequential relationships were established in various combinations (i.e. Bi-Zone [parti]— Grid [Spa. Org]—Hierarchy or Repetition [Ord. Sys]) (see Figure 1).

Moreover, the results indicated that certain conceptual issues were related to some specific capabilities of a particular media. Some of the findings showed, however, that at least some conceptual ideas such as axis, linear organizations, symmetrical order and nine-square parti were universal and, thus, that the development of these concepts was not necessarily limited to particular media. One explanation is the ease of constructing those concepts within the given design problem and constraints. Another explanation is the popularity of these concepts among the students. Certainly, this issue needs further exploration.

Space Making

Overall, digital media group appeared to be more actively involved in space making activities than the manual media group. In comparison, the digital media group produced significantly different results on most measures related to architectonic space making and these differences suggested a relationship between media and measured architectonic design issues.

The first and one of the significant differences between the two groups was the definition of the spaces. According to the results, students who used digital media developed designs that suggested more understanding of architectonic space and clear distinctions between the conceptual and perceptual spaces. The proportional differences between the groups (well-defined v. perceived) implied that certain attributes of media made a notable difference in space definitions. In comparison to the other group, the digital media group created significantly more well-defined spaces and qualitative analysis later suggested a strong correlation between the well-defined spaces and better design quality.

These definitional results were related to the results of the shape of the spaces. The digital media group created 62 percent more orthogonal spaces than the manual media group and since the qualitative analysis showed a considerable correlation between these issues, this difference was also reflected in better design quality. The geometrical shape was one of the important characteristics of spaces and, since the spatial volume depended partially on the edge definitions, it was related to the spatial definition of spaces. In the formation of space construction, the shape served as the key element in the vocabulary of the architectonic definition. The orthogonality of spaces did not only support these definitions but also articulated the spatial continuity.

In all, students were encouraged to explore the design at each stage using study models, so that the three-dimensional implications of design decisions were more fully understood. With movement and sequence as important characteristics of the spatial composition, interior views and the general architectonic quality of the design as seen from the inside took on greater importance.

In the manual media group, students utilizing traditional cardboard study models seemed to not carefully examine the spatial relationships and organization of spaces. Therefore, many opportunities to enrich the design from this point of

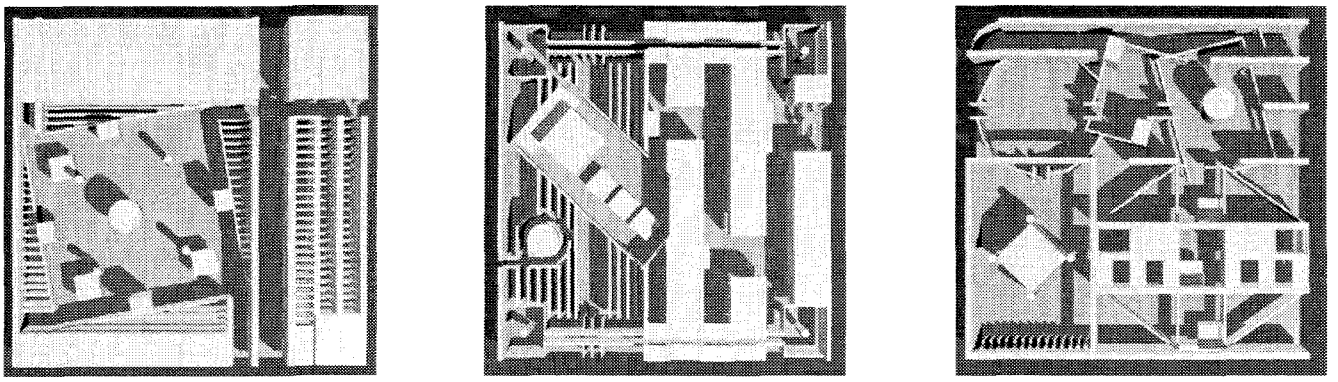

Figure 2: Spatial deformations in manual media group projects

view were lost. For example, the diagonal or oblique views that existed within a design structure that was primarily orthogonal were easily overlooked if the visual representation was limited to the two-dimensional plan view. Manual media students naturally attempted to overcome the presumed monotony of the grid by inventing skewed, shifted, or warped planes, which immediately displayed their nonconformity in plan (see Figure 2).

These issues were further supported with additional findings. Space construction results indicated that the digital media group relied more heavily on the primary wall planes to create their spaces whereas the manual media group used mostly horizontal and secondary planes for space creation (in total numbers). This was an important finding to support the argument that with the help of digital media, students in that group were able to see the spatial value of primary planes and utilize them in space making. Although secondary wall planes were easier to use to create spaces because of the flexibility of orientation and horizontal planes were practical to cover unsolved organization, the digital media group saw primary planes as major space definers. The main reason was the control of this group over the spatial organization, various spatial relationships and the entire design composition. The manual media group's reliance on other planes, especially on horizontal planes indicated that their efforts were not focused on considering the spatial composition. Simply, they could not solve the spaces, their organization, and their relationship as successfully as the digital media group. Almost all of the other space-related findings, especially roof/space ratio support this explanation.

Form Building

The results indicated that media influenced the typology of design by effecting certain elements of form that contributed to the development of form building. Overall, digital media group articulated their planes, emphasized the penetration and continuity of its surfaces, handled the openings to visually organize the volumes, utilized their object elements and formed more balanced compositions than the other group.

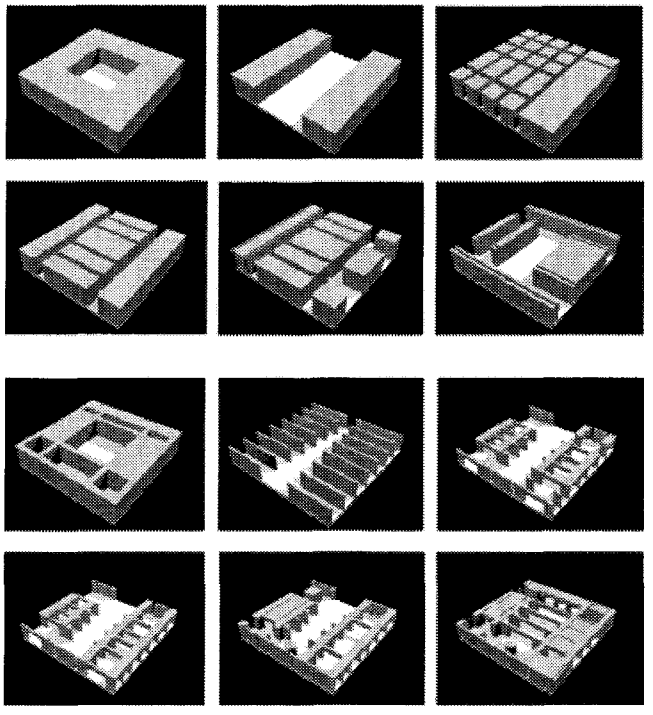

Figure 3: Sequential exploration of form in a digital media group project

These results suggested that the digital media influenced the exploratory phase, where the search for possibilities occurred in a deliberate and controlled manner. For example, as seen in the figure below (Figure 3), upon arriving at an initial *parti*, digital media users built digital models on the computer. At this point variation and transformation was easily accomplished and a number of alternative studies were created for comparison. Each new model was completed in terms of graphic representation, as this task was instantaneous on the computer. Various views, both external and internal to the model, were examined. The experience of sequence as a progression was studied in a series of perspective views. Subtle changes affecting interior lighting conditions (natural

Descriptive Statistics

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	# Missing	Range
Digital - Spatial Design/ Composition/ Balance	-1.000	1.552	.231	45	-5.000	0.000	0	5.000
Manual - Spatial Design/ Composition/ Balance	-2.511	2.149	.320	45	-5.000	3.000	0	8.000

Table 1: Descriptive statistics of balance in both groups

Regression Summary
Design Quality vs. Planes/Primary/Porosity

Count	90
Num Missing	0
R	.655
R Squared	.429
Adjusted R Squared	.423
RMS Residual	.721

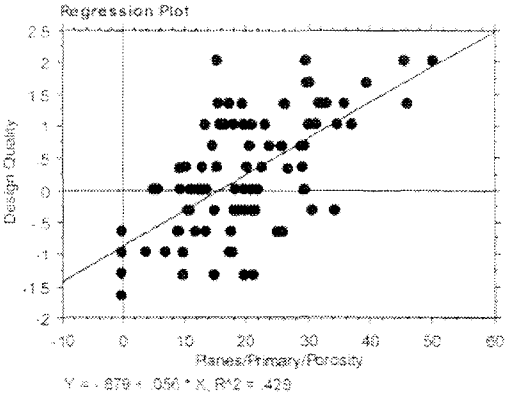

Table 2: The results indicated a strong correlation between the porosity level of primary planes and the overall design quality

light) were tested by trial and error. Although these kinds of comparative studies have always been encouraged by critics and are common practice in some design offices, the amount of time involved in creating precise drawings or models by traditional means is a frequent dissuasion to the single student working alone.

Another important finding was the compositional differences between the two groups. The results indicated that media made a significant difference on formal compositions in student designs. The digital media group created more balanced compositions than the other group (see Table 1). Therefore, in comparison, their designs were clearer, more consistent and were assessed of having better design quality than the manual media group.

An unexpected finding was that contrary to my expectations, the results showed almost no difference in spatial density for both groups. It was found that both groups had similar densities regardless their involvement of different media. It was unclear why spatial density was not effected by media choice. Further studies are needed to investigate some possible explanations such as be the limitations, constraints and scale of the project.

Overall, these findings indicated that digital media help to enable the study, exploration and formation of visual and spatial continuity between different architectural formal elements and therefore effected the basic principles of form in design. This suggests that digital media allow students to see their designs as a formal organization and to develop balanced compositions.

Design Quality

Overall, the results showed considerable differences between the two groups. In a randomly selected sample, all design issues and projects (with one exception) were evaluated favorably for the digital media projects. Since this measurement was taken based on categorical survey questions, it was possible to identify certain aspects. Accordingly, in digital media projects, "Spaces" and "Design Concepts" received significantly higher quality scores whereas manual media projects scored below average.

These results were later verified with a second round of evaluations of all samples and the results of the second evaluation correlated with the previous one by favoring the digital media projects. On average, the digital media group scored above average (0.56) and the manual media group below average (-0.16) on a Likert scale. Furthermore, comparative analyses showed significant correlations between the quantitative and qualitative results and suggested a relationship between media and design. According to the results, certain design issues were correlated more than others. For example, "donut" and "nine-square" partis, "grid" organizations, "datum" and "repetition" ordering systems in design concepts category seemed to be related to better design quality. All of these conceptual types were found overwhelmingly more often in the digital media group's projects. Other design issues, such as planes' porosity, spatial definitions, orthogonality, balanced compositions were significantly different in the digital media group's projects and these differences were correlated with better

design quality. For example, The more porous the primary walls, the higher the design quality became ($r = 0.65$, $p=<0.0001$) (see Table 2).

One interesting finding was the combined effect of these issues on design quality. The multiple regression results showed that these issues made individual impacts on the overall design quality in varying degrees but this impact was increased when they were used all together. Another interesting finding was the one-sided, independent effects of some issues. For example, the accessibility of the openings correlated significantly with higher design quality scores, whereas non-accessibility did not seem to make any qualitative difference. In other words, when a design included both accessible and non-accessible openings, the number of accessible ones made a positive difference even though there was no effect for non-accessible openings. The same effect was seen in some other design issues, such as space definitions, space entrance, and object element usage. Moreover, certain important design issues seemed to be missed by the evaluators. These issues were related to the previous one and could even provide an explanation. For example, the surface coverage of horizontal planes was correlated with better design qualities whereas the ratio of space to horizontal plane showed almost a zero correlation. One explanation would be that the evaluators either missed or ignored or were not interested in this kind of ratio while assessing the quality of the project. Regardless of their spatial relationships, using horizontal planes seemed to contribute to the density of the form and that influenced the evaluators. Other explanations would be the identification of the design issues, operationalization, evaluation method or a combination of these. In either case, this issue needs further testing.

Overall, these findings suggested that media not only created quantitative differences in design projects but also effected the quality of the projects. The effects of digital media on basic design properties seemed to have a direct and essential impact in the way architectural design was produced. Students appeared to develop a better understanding on the nature of the design project and made better design decisions.

Furthermore, the results suggested a substantial correlation between the quantitative and qualitative aspects of design. According to these findings, it is fair to conclude that there is a considerable relationship between the media and architectural design. The type of media not only changes some quantifiable design parameters but also affects the quality of design.

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