

Comparing Notes, analyzing teachers' and students' perceived concept importance based on highlighting architecture study documents

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Key words; **Highlighting, Patterns, Study documents.**

1. ABSTRACT

Precedent studies are an important learning strategy for architectural design (Oxman 1999). Students are often instructed to search for interesting case studies and articles from published design folios or architectural magazines. The components of these case studies usually include graphic representation such as diagrams, drawings and pictures of the design, as well as textual information that describes the site condition, design intent, and innovative techniques used in the project. Some articles also include reviews and critiques from architectural historians or art critics.

Many students use highlighters to mark on the document to call out ideas and concepts that they perceive as important. Text is considered an important part of design representation (Dong 1997, Tang 2006). Annotation is a behavior that facilitates text comprehension (Wolf 2001). If text highlighting reveals what concepts and ideas are perceived as important by students, the question is, then, if a teacher is given the same case study document, would he or she also highlight the same key words and concepts? How different might they be?

We are interested in identifying how these design concepts are perceived differently by students and teachers. The hypothesis is that for more experienced students their perceived important concepts would be closely related to what the teacher marked as important.

Our study is consisted of two parts. The first part of the research was to collect from study texts what students would mark as important. We consulted architectural professors to select a set of study documents to give to a group of architecture students and ask them to highlight important keywords and phrases. We then gave the same article to their instructors to perform the same task and collected their responses.

These student notes with highlighting marks represent the level of understanding of the subject matter by the students. The notes from the teachers provided us the information of what concepts they perceived as important.

2. METHODOLOGY

2.1. RESEARCH APPROACH

The first phase of our research aims to identify the patterns which helps us to understand the relationships between the level of importance defined for concepts from both teachers and students.

We started by asking an associate professor of the College of Architecture at Georgia Institute of Technology, to review a particular study material for her area of expertise. She was asked to identify, using a yellow highlighter, all those text elements she considered to be important for the correct understanding of the subject matter contained in the document.

We designed our experiment to obtain information about the level of importance perceived by students when reviewing the same document. We asked a group of graduate students from the the College of Architecture at Georgia Institute of Technology to review the same study document. The group was composed by three females and three males. Their age ranged from 25 to 36 years old. Most of them

were highly qualified. Their educational level ranges from recently admitted PhD students to a Post Doctoral Fellow. The basic demographics of the participants in the experiment are shown in Table 1.

Table 1. Participants demographic information

Name	Age	Educational level
Ann	26	First year PhD Student
Betty	27	First year Masters Student
Carol	35	First year PhD Student
Paul	33	Second year PhD Student
Robert	29	Second year PhD Student
Steve	36	Post Doctoral fellow

We selected students with high level of expertise in the subject area treated in the study document in order to compare their marking patterns to the ones marked by the teacher. The students were asked to identify two different kinds of concepts in the study document. They were asked to identify by highlighting in yellow all the concepts in the study document they completely understood both the meaning and the context of the concept. The purpose of including the contextual relationship of the concept is to understand how these students understand the text beyond isolated concepts.

The students were also asked to highlight in pink, all the concepts they were not sure either about the meaning or the context but still considered important in the study document. The reason for gathering this information is so that we could assess if the students understand which elements of the text were of significance even though they might not have fully understood them yet. Our hypothesis is that for more experienced students their perceived important concepts would be closely related to what the teacher marked as important.

2.2. EXPERIMENTAL PROCEDURES AND CONSTRAINTS

We asked the participants to highlight no more than three consequent words, the we re also asked not to go back and review previous markings. To avoid the possibility for some of them correcting their own markins, and also to prevent the highlighting of the entire paragraph or a large area of it.

2.3. TEXT ANALYSIS

The text selected for the experiment is “Computing in architectural design : reflections and approach to new generations of CAAD ” by Rabee M. Reffat (2006) within the document we identified the following number of discourse units:

- 11 Sections
- 77 Paragraphs
- 3 Graphic components
- 2 Table components

We established an analytical framework for the highlighting protocol study. The document was divided in different scales of discourse units. The units identified are:

- Page number: 1 to 16
- Section: A to L, organized in alphabetical order, as they appear in the document.
- Paragraph: each paragraph was identified by the page number in which it is located and a sub-index identifying the position of it on the page.
- Sentence: consist of a subject and a predicate.
- Graphic component: refers to either a diagram or a picture. Graphic components were identified using the same classification scheme used for the paragraphs.
- Table component: refers to information displayed by using rows and columns. Table components were identified using the same classification scheme used for the paragraphs.

A section usually contains a couple of paragraphs, one graphic and some table components. Each paragraph contains several sentences. Those paragraphs that span two pages were considered as one when dividing the document in units (Fig 1).

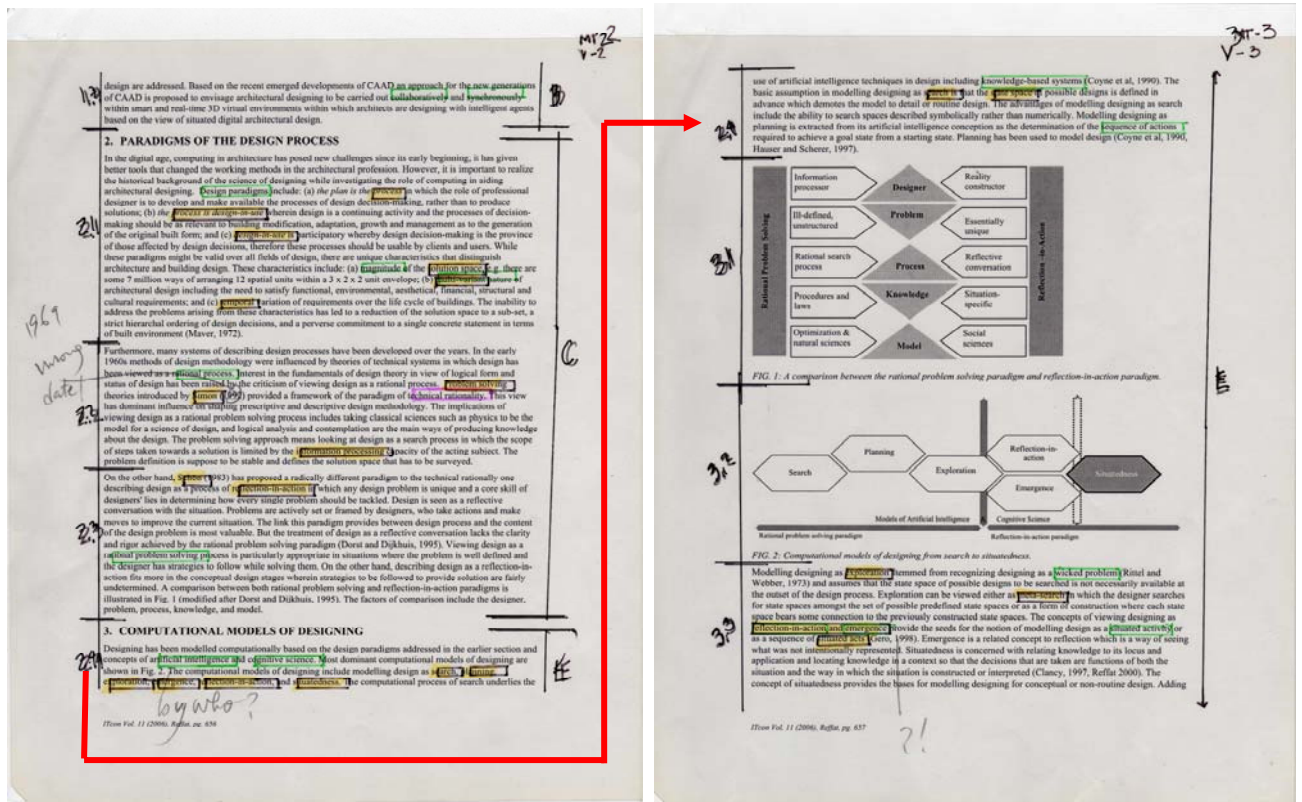


Figure 1: Pages 2 and 3. Paragraph 4 of page two (numbered as 2.4) is identified in the label page 3 (top).

3. EXPERIMENTAL SETUP

The experiment was set up to collect two different types of data. We obtained information about the amount of highlighting operations performed by the student participants. This information would help us understand the level of comprehension by students when evaluating a study document. We also collected the marking patterns from the teacher. We could use this data to understand the level of similarities between the highlighting patterns displayed by the students and the teacher.

Why are we doing this kind of experiment? We are interested in the implication for education. If we can understand and assess the learning patterns of students by looking at their highlighting behavior in the text documents, maybe in the future we will be able to build intelligent paper capable of understanding the highlight behavior

of students and use that to either help reveal important study patterns and strategies to help the students or the teachers to improve their own teaching efforts.

Our hypothesis is that the marking patterns done by students with higher level of expertise will be closer to those by the instructor than those done by novice students. Our research method is to count the patterns and score them and see if expert students have higher matching score to the teacher's pattern. We counted each of the highlighted elements produced by the test subjects. We organized the gathered information under two categories, these are: (1) Elements highlighted in yellow are called known text elements, (2) Elements highlighted in pink are called unknown text elements.

Table 2: Spreadsheet showing the numbers and the locations for the highlighted text elements.

document section	A	B	C	E	D	F	G	H	I	J	K
Ann(known)	11	23	7	13	51	15	67	68	35	0	0
Ann(unknown)	0	0	4	10	0	0	0	0	0	0	0
Betty(known)	8	16	23	19	16	16	21	26	0	0	0
Betty(unknown)	0	1	0	0	0	3	2	0	0	0	0
Carol(known)	1	6	18	13	4	0	8	6	8	0	0
Carol(unknown)	5	0	6	4	9	7	7	6	1	0	0
Paul(known)	0	13	9	4	8	9	25	19	10	0	0
Paul(unknown)	0	0	7	4	3	2	6	1	0	0	0
Robert(known)	8	10	5	9	16	48	62	32	31	0	0
Robert(unknown)	1	2	1	0	2	5	11	6	1	0	0
Steve(known)	9	28	34	17	20	27	40	56	32	0	0
Steve(unknown)	1	7	3	6	7	6	31	6	0	0	0

3.1. DATA GATHERING.

The extraction of the experimental data was performed by transferring both, the positions and the colors of highlight markings for each individual text element to a transparent plastic sheet. Then the data was compared by overlapping the transparent plastic sheets containing the patterns obtained from both students and the teacher, in order to verify levels of similarity.

To identify how similarly both parties perceived the significance of some particular concepts in the study document, we developed a scoring scheme to measure the proximity of text elements. We used the teacher's copy as a template document. This document contains solid yellow markings on each page. The yellow markings were then transferred to the transparent plastic sheet with black bounding boxes, to avoid any possible confusion with the highlight markings extracted from the students' documents.

We transcribed the marking patterns of all the students as color boxes on transparent sheets. These boxes bound the text elements identified by the students. Each page of the study document has a corresponding transparent sheet containing pink and yellow boxes.

Below is the scoring scheme:

Direct correspondence = 4: the compared text elements are located in the same position.

Sentence correspondence = 3: the compared text elements are located within the same sentence.

Paragraph correspondence = 2: the compared text elements are located within the same paragraph.

Section correspondence = 1: the compared text elements are contained within the same paragraph.

Non correspondence = 0: no correspondence found between the compared text elements.

The scoring was assigned only to the closest correspondent element marked by the student in relation to those marked by the teacher, as seen in (Fig 2). This approach was used to avoid the possibility of high scores from excessive highlighting.

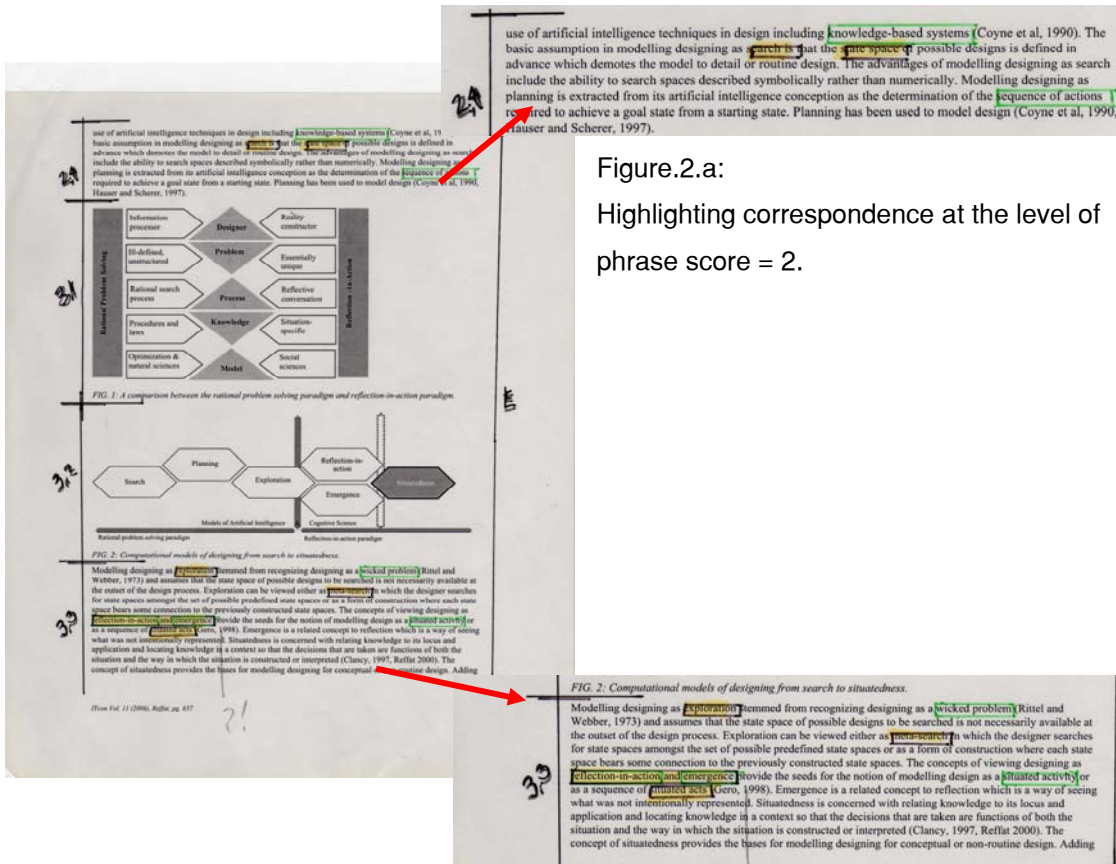


Figure 2.b:
Highlighting correspondence, direct
Correspondence score = 4.

Figure 2: Picture showing the overlays of the extracted data from Robert's highlighted document page 3 when compared to the instructor's study document.

The score pertaining to each individual was placed in a table (see table 3) corresponding to different discourse units defined for the text used in the experiment. This table enables us to easily identify areas of both low and high scores within the analyzed study text. As shown in Table 3, there is no score entry in section A. Section A is the introduction to the paper and is not perceived to be important by the participants.

The scoring was placed in a table for the interpretation of the data. The table is organized as follows: from left to right the labels are discourse units, section, page, paragraph, sentence correspondence (sc), and direct correspondence (dc). Scores are placed in the intersections between discourse unit element and the the columns of the names of the test subjects.

experimental data														
subject ID			Ann	Betty	Carol	Paul	Robert	Steve						
section	unit/page	paragraph												
1														
A			0	0	0	0	0	0						
		1 1.1												
		1 sc												
		1 dc												
		1 1.2												
		1 sc												
		1 dc												
		1 1.3												
		1 sc												
		1 dc												
		1 1.4												
		1 sc												
		1 dc												
B		1				1								
		1 1.5												
		1 sc												
		1 dc												
		1 1.6												
		1 sc												
		1 dc												
	1+2	1.7	2				2							
	1+2	sc			3									
	1+2	dc		4				4						
2														
C		2												
		2 2.1												
		2 sc			3									
		2 dc	4	4	4		4	4						
		2 2.2												
		2 sc		3			3							
		2 dc	4		4			4						
		2 2.3				2	2							
		2 sc												
		2 dc		4	4			4						
D	2+3													
	2+3	2.4			2		2	2						
	2+3	sc												
	2+3	dc		4										

Table 3: Example of the scoring table

The graphing of the scoring data presents identification of a marking pattern behavior for all the students in the group. There are sections of the text which clearly are interpreted as more important by the students, like C, E, F, H, and I were assigned high level of importance by both students and the teacher.

3.2. FURTHER DATAT ANALYSIS

The first part of our study focused on assessing the comprehension levels of the study documents by the student. Patterns of the Known and Unknown elements are obtained and analysed. We recorded both the numbers of Known and Unknown text elements found in the study document. Relating these previously defined discourse units helped us to identify areas of the text where students assigned a high level of importance to the information displayed in the text.

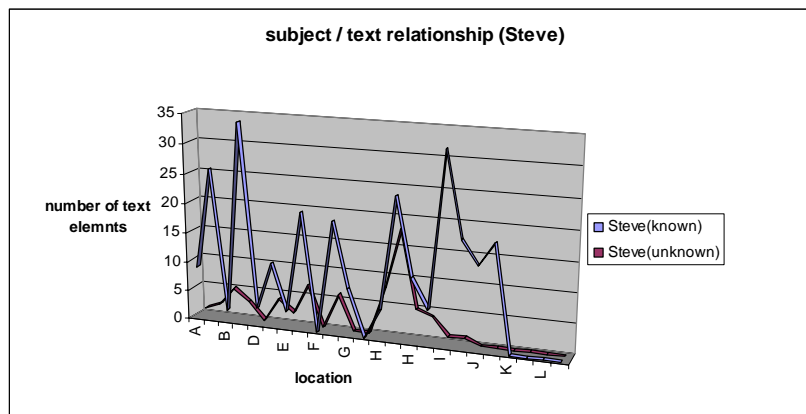


Figure 3: The pattern of known, unknown elements for Steve.

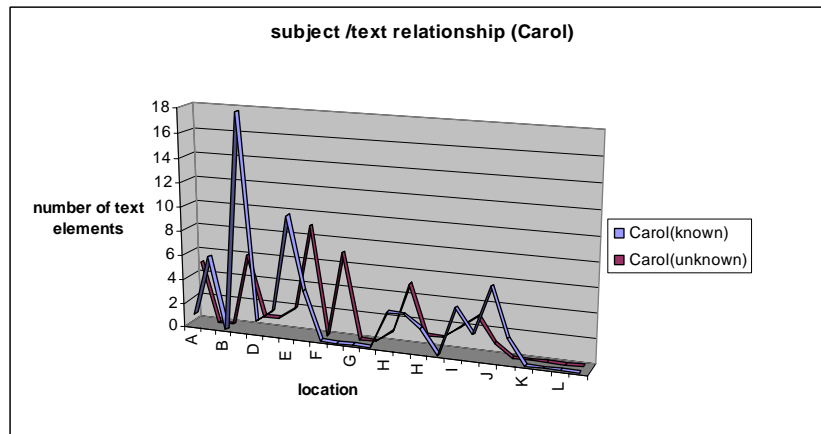


Figure 4: The pattern of known, unknown elements for Carol.

We found two main areas where students showed high levels of comprehension as compared to the instructor highlighting patterns. This might indicate a correspondence on the understanding of the information contained in the text. Although these high level corresponded paragraphs have a similar word count (between 205-228) there is no morphological similarities between the paragraphs. The locations of these paragraphs in relation to the page layout is completely different. The one contained in section F of the document is located almost on the top

of the page. Figure 5 shows section F highlighted in yellow. Figure 6 shows section H bounded in red.

the notion of attachment to framework of Fracchiolani-Stratton (1990) provides a model of shared Fracchiolani-Stratton framework (Cao and Kazanjan, 2004).

EVOLUTION OF COMPUTER AIDED ARCHITECTURAL DESIGN IN THE DIGITAL AGE

Since the beginning of digital age, new technologies have influenced people in different ways in which life is not anymore as before, the world is different and people become more open and knowledge worldwide becomes more accessible. However, there are continuously more perspectives and opportunities, people are encountering problems more and more before digital age. The digital age has posed new challenges and given people tools with which the working methods have changed. Architecture is still searching for a consistent practice with the use of computers in designing. The evolution of computer aided architectural design (CAAD) can be viewed through the generations of CAAD. In the first generation of CAAD, analyzing designing commenced from the view of systems method that divide reality into a small number of subsystems with specific and clear influence. In accordance with the theory of general systems, each system acts in relation to others on the basis of direct and linear coupling with a deterministic approach of association. The association of the General Systems Theory have become the methodological basis for the developed methods of aiding design. Systemic designing methods can be divided into two groups: strategic and tactical methods. Strategic derived from scientific research methodology analysis, (a) analysis-synthesis-evaluation, (b) divergence-analysis-convergence, while systems-convergence-evaluation represents the dialectic creative approach. Tactical methods include that of spatial distribution and rules and architectural rules (Apostolov, 1999).

The effort to present the formal structure of the design process, the formal structure of the design process, the point of view was not that successful, however the architectural thought is supported by abstract logic. Abstract logic means to signify a qualitative exploration that serves as a crystallization of the complexity and richness of the world, rather than a reduction of its reality through dispensing its concreteness. At the core of architectural creation is the transformation of the concreteness of the real through transparent logic into spatial order (Aoki, 1993). Therefore, the first generation methods had many drawbacks including: deterministic and linear approach of the design process, limited scope to solve functional problems, and a lack of graphical interfaces for communication between users and the computer. The second generation of CAAD facilitates designer's communication with the computer whereby software packages were released to enable one to draw on the computer screen without having to know any programming language. Since then, designers are using computers as a digital board to be alternative to the conventional drawing board. CAD systems are used to produce technical drawings and 3D computer models. The typical use of CAD systems at subsequent stages of designing can be illustrated as shown in Fig. 3. Little computer support has been provided for both concept and exploration of various useful alternatives. The primary computer aided support is basically for developing design documents, construction and working drawings and generating presentation drawings in 2D and 3D multimedia format including animation and movie. Generative computing support has been given to the design analysis including structures, lighting, acoustic, mechanical, space system, etc. In the second generation of CAAD systems, there was no real difference that can be identified from conventional design support systems including the drawing tools of pencil, drawing board and brush with efficient and powerful digital replacements. The computer is transferred into a drafting machine and CAAD meant more Computer Aided Architectural Drafting than Designing. It is arguable that these systems provided the architect with more time to spend on the creative stages of the design process. However, it is not quantifiable that such systems have enhanced the acceleration and development of the technical development of building design and generating building drawings that are away from the cases of right angles and straight lines. On the other hand, the Rensselaer Chapel and the TWA airport terminal in New York, designed by Le Corbusier and Saarren respectively, are just examples of magnificent architectural forms created without the use of computer (Apostolov, 1999).

Figure 5: Section F bounded in red.

FIG. 3. Computer aided support to various stages of the design process in the second generation of CAAD.

5. COMPUTER AIDED ARCHITECTURAL DESIGN BETWEEN DEADLY SINS AND ARGUABLE VIRTUES

Akin and Anadol (1993) addressed "what is wrong with CAAD?" and noted that Computer Aided Architectural Design (CAAD) is far from fulfilling its expected role as assistants to the designer, providing a medium and set of tools for the designer, in the professional or the academic context in all aspects of the design activity. Akin argued that CAAD development should be directed towards greater impact on practice by means of principles that are related to the steps used to construct CAAD tools for conception, defining the goal, developing the product, fitting out the product, and drawing. Mauer (1995) has provided a critical view of the direction of research and development in computer aided architectural design. His criticism was set out as seven deadly sins including macroscopic, digital, compatible, unsustainable, failure to validate, failure to evaluate and failure to criticize. The seven deadly sins of CAAD are elaborated in Table 1. CAAD researchers and educators should not be distracted by Mauer's (1995) critical view on the direction of research and development of CAAD, but on the contrary it is important to the future role of computing in architecture as enacting the advantages and virtues of CAAD as Mauer (1996) later remarked. Kwan (2004) has endeavored to illustrate the inevitability of facing the "techno-crisis". Distinguishing between wasteful repetition and productive re-composition as a skill since reworking is an essential activity in discovery that is recognized more readily in art than in science. Therefore, it becomes an important research activity to revisit problems. Therefore, revisiting in Mauer's definition might be a necessary condition of progress, at least in a field of endeavor such as CAAD, wherein the link between practice and research in CAAD is weak. It seems to be a necessary condition of CAAD that one struggles between the holistic experiential goal of architecture and the reductionist nature of science (Kwan, 2004). Furthermore, it is essential to visit some of the benefits of importing concepts and procedures from other disciplines to architecture, for instance, artificial intelligence research brought a better understanding of design activities and opened the field for new support methods, genetic modeling and genetic reasoning research formed the foundation for CAAD programs that enhance the transmutation of architect's worthwhile design methods research brought much needed knowledge into the realm of design (Silvestri, 2004).

Mauer (1998) and Cao (2002) noted the prospects of CAAD and the advances of information technology in building design respectively. Mauer (1998) reviewed with reasonable detail a variety of CAAD systems developed since 1950 for the first program that generates a single floor plan layout which minimized the pedestrian travel within the building as the origin, energy efficiency systems, integrated apparatus systems, design decision support systems, simulation of form, photometric and animation, and the virtual and augmented reality systems. Mauer (1998) noted that "in difficult, perhaps unresolvable, however, to maintain a realistic and panoramic view of the CAAD world in face of such a wealth of innovative, relevant and enjoyable developments". Cao (2002) remarked the advances of using computers in the building industry commensured with research into automating structural analysis through the development of the matrix method of frame analysis, developments of environmental analysis of buildings and developments in construction project

management. Most recently Karamanlis (2004) questioned the validity of CAAD study since by Mauer (1995) and in contrast has attempted to bridge the seven deadly sins to CAAD as represented in Table 2. Some of the virtues argued by Karamanlis (2004) have been retained by the Author and all terms are placed between parentheses. The primary reason of retaining is to make them more applicable to CAAD development.

TABLE 1. The seven deadly sins of computer aided architectural design.

Deadly sin of computer aided architectural design	Retained virtues
Deadly sin: neglect	Overlooking the direct time required for understanding the larger design process. Collaboration is still vital to today's CAD community. Most of PRD, those doing working like 70-drafting, 40-drafting, 30-drafting, 20-drafting, 10-drafting, 5-drafting, 1-drafting.
Deadly sin: digital	Current CAAD often does not look as what need before. This is observed with the emergence of new ideas, with increasing frequency, in the CAAD field that have nothing to do with what abstract and distant design work.
Deadly sin: compatible	Adherence of new course of discipline. Consistent with importing concepts and procedures from other disciplines. Development through to artificial intelligence means to new digital methods that free the spirit of architects to explore the unknown and the unexplored of architectural design.
Deadly sin: unsustainable	Research and development are focusing on solutions more than on architectural design products. Efficient and elegant building the practice of architecture with less attention to achieving design solutions with improved quality to building design and users. Innovation, attitude to do what is done, style rather than solution has been considered as the signature of those for progress, cost-effectiveness and environmental sustainability.
Deadly sin: failure to validate	Constructing a practice of critical re-evaluation of design with prototype implementation or collaborative models.
Deadly sin: failure to evaluate	Little or no critical evidence of investigation (including models and feedback), of the quality and feasibility of proposed design solutions in the technical building and practice.
Deadly sin: failure to criticize	Not recognizing any critical failures in the research and development activities and not act upon its assumptions.

TABLE 2. Comparative virtues of computer aided architectural design in contrast to the deadly sins.

Deadly sin	Retained virtues
Deadly sin: neglect	Provision: Careful consideration to the implications and potentials of architectural competition while exploring an appropriate use of developed shared methods to critical reflection and the practice.
Deadly sin: digital	Trust (PRD): Development of creative, comprehensive, consistent and relevant theories by careful application of CAAD and appropriate choice of the methodology and techniques of CAAD study with consistent, transparency and focused principles.
Deadly sin: compatible	Originality (Creativity): Establishing a core research discipline based on the unknown and the unexplored of architectural design.
Deadly sin: unsustainable	Empowerment: Enhanced emphasis on building technical and performance with design approach and generative systems to CAAD. Focus on Computational design methods and automation of computer's intelligent power complement human creativity in an architect, creative manner while achieving optimal results in high performance.
Deadly sin: failure to validate	Practice (Impact): Research should be based on well-founded and well-defined operations with the foundation of consistent and reliable principles.
Deadly sin: failure to evaluate	Efficiency (Productivity): Developing rigorous and consistent evaluation principles.
Deadly sin: failure to criticize	Sound judgment (Quality): Developing, using and illustrating of specific and reliable criteria. Comprehensive process research instead of concrete propositions of expectations to establish well-founded practice and design methods.

6. RECENT EMERGED DEVELOPMENTS OF CAAD

There have been various recent emerged developments of CAAD. It is beyond the scope of this paper to thoroughly investigate and/or compare them. However, it is critical to address the most important developments

pertaining to shaping the future of CAAD and that will also provide a logical bridge to the proposed approach of the new generations of CAAD as outlined in the following section. These important emerged developments of CAAD are illustrated graphically in Fig. 4 and include virtual collaboration and communication in design, digital fabrication, 3D virtual design, development of CAAD, and intelligent agents in design.

6.1 Virtual Collaboration and Communication in Design

Initially, the mode of working with digital tools assigned a user to a machine wherein tools were formulated as a singular activation of preparing data and submitting them for processing. The complexities of design, therefore, were reduced to individual activities of groups of participants. Using digital tools for modeling, rendering and representation while in a single user system fail to apply digital media in a manner that effectively supports design. Architects work to teams and collaborate on projects. The medium needs to address their creative and communication roles of the designer. Studying the activities of designers and comparing on-site and digital activities has led to discover that designers working together on tasks in different environments engaged with the task in very different ways and that the assumption that high bandwidth social interaction was essential in supporting design was not necessarily the case (Cao et al., 1998). Furthermore, it was found that the limited channel of a chat line, where communication is engaged in text mode, appears to support the development of richer design investigation through continuing development of ideas (Cao and Cao, 2003). Virtual collaboration does not only enhance the design process but also changes the tools allowing designers to work together more easily and better.

6.2 Digital Technics and Fabrication

Digital is an evolving methodology that integrates the use of design software with traditional construction (Shelley and Seebach, 2000). A breakthrough came in the early 1990s, when Frank O'Geary and the technical team in the O'Geary office began seriously to explore the use of digital technics and fabrication technologies on complex projects. The goal was to support efficient design and construction of buildings with curved surfaces and generally complex, non-orthogonal forms. O'Geary and Cain (a system that has been developed primarily for use in manufacturing industry) that offered a high degree of integration of design and CAD/CAM (Computer Aided Manufacturing), fabrication capabilities. This allowed developing complex and non-orthogonal buildings but entailed more explicit decision per square meter than repetitive building. Furthermore, digital three-dimensional modeling of buildings is generally more time-consuming and costly than two-dimensional drafting of plans, elevations, and sections (Middell, 2006). Models of design capabilities of construction, structural and dynamic transformation are replacing the matrix norms of conventional processes. The predictable relationships between the design and representations are abandoned in favour of computationally

■ generalized complexity. Digital architecture is profoundly changing the processes of design and construction. By integrating design, analysis, manufacturing and assembly of buildings around digital technology, architects, engineers, and builders have the opportunity to reinvent the role of a "mass-builder" and reorganize the currently separate disciplines of architecture, engineering and construction into a relatively seamless digital collaborative enterprise (Kohovits, 2001).

6.3 Virtual Design Environments

■ The concept of virtual environments has emerged from advances in computer networking, image processing, modeling, animation, and multimedia representation (Orloff and Mohr, 1997). Virtual environments that mimic the spatial arrangements of the physical world have changed the role of 3D CAD systems from drafting to producing blocks of the new 3D virtual environments. Virtual Environments (VEs) are attractive platforms for learning in which they can provide opportunities for new kinds of experience to enable users to interact with objects and navigate in 3D space in ways not possible in the physical world. The key property of VEs is their ability to explore. Immersion in 3D environments is highly motivating, inducing users to spend more time on a given activity. Furthermore, virtual environments encourage people to be more active in the way they interact with external representations, through having to continuously choose their position and viewing perspective when moving through the virtual environment. Utilizing virtual environments in architectural design addresses the concept of designing with computers (e.g. in a paperless design studio), to a multi user real-time 3D virtual environment for achieving collaborative designing (Orloff, 2008b).

6.4 Intelligent Agents in Design

■ An intelligent agent is an autonomous system situated within an environment, it senses its environment, maintains some knowledge and learns upon obtaining new data and, finally, it acts in pursuit of its own agenda to achieve its goals, possibly influencing the environment. Agents in Design still in early evolution stages whereas intelligent systems in a relatively new area within artificial intelligence. Multi-agent systems provide means to model distributed computational process, and as such computational design agents. Computational intelligent agents enjoy the following properties: autonomy, reactivity and pro-activeness whereby they do not simply act in response to their environment, they are able to exhibit goal-directed behavior by taking the initiative (Woodledge and Jennings, 1995). Intelligent agents are expected to influence and change the environment within which they function. Users of work-to-work multi-agent systems make use of agents during their work routine.

■ Designing with computational agents is at the cutting edge of current design computing research. This agent approach is derived from recent developments in cognitively-based design agents, where design is considered as a situated act. A design agent might have few kinds of reasoning, sensation, perception, conception, hypothesize, and action (Oero, 2002). For instance, Shimodera (2001) developed a computational model of creativity based on a process of novelty detection. A creative design agent is an agent that uses the results for novel designs to guide its design actions. Computational models of creativity provide general-purpose, knowledge-based heuristics to guide the search for potentially interesting, and possibly non-obvious designs. Determining interestingness depends upon the knowledge of the agent and their computational abilities, things are boring if either too much or too little is known about them. Hence situations that are similarly-different to previously experienced situations are the most interesting and that is what we mean when we say that something is novel. A novel situation is one that is similar enough to previous experiences to be recognized as a member of a class but different enough from the other members of that class to require significant learning. Furthermore, Orloff (2008a) developed a system of intelligent design agents that supports design exploration and creativity within the domain of architectural design. Creativity in architectural design computing is viewed as an emergence of new forms and shapes or relationships between forms and shapes from which new concepts are discovered.

6.5 Situated Digital Design in Architecture

■ Empirically-based research uses the experimental paradigms in which experiments are set up and then data is collected and analyzed to produce a set of results. These results are then used as the basis of either the development of a hypothesis or the confirmation of a hypothesis about designing. The experiments are typically developed to provide evidence for a particular theory or cognitive model of designing. Typical approaches to

■ empirically-based design research include direct observation of the results of designing, surveys of designers' perceptions, and protocol studies of individual and collaborating designers. New protocol analysis methods have been developed and are being applied to produce novel results concerning the behavior of designers as they are designing which has significance for the development of computational tools for designers. Empirically-based research produces results by which a greater understanding on how human designers design is required. Such knowledge has implications for both how information technology can be interfaced with human designers and, perhaps more importantly, provide new conjectures for design computing research in architecture to explore in order to provide the foundation for more useful tools for designers.

■ The evolution of digital design is being driven by its own body of theoretical research, and a culture of discourse, is beginning to evolve unique methodologies. Rather than the employment of digital technology, it is these emerging conceptual structures that strongly influence the logic of architecture and its design methods (Cross, 2006). Computational models of designing have largely been founded on fixed views of the world, often derived using artificial intelligence models focused on modeling and representing designed objects. These models were based on a perspective of computing that assumes that the underlying programs are unchanged by their use and are not affected by where or how they are used as a core of the foundation of objective knowledge. These models have been useful but have proven to be inadequate to describe much of the detailed behavior of designers observed in protocol studies (Suhler and Wigston, 1992). Such behavior can be more modeled using the notion of situated computing and from the basis of situated design computing, that is the inclusion of situated concepts into design computing. Situated computing makes use of concepts from situated cognition (Clancey 1997). The fundamental difference is between modeling all knowledge prior to its use and allowing the knowledge to be developed and provided in the interaction between the tool and its environment. The effect of this is to provide a computational system with experience based on its interaction with its environment. This experience is then used to guide its future actions. The effect of this generated experience is to provide the tool with the capability to respond differently when exposed to the same environment again depending on the experience it had in between the two exposures. The objective knowledge within the tool is unchanged, only the knowledge that is the result of the interaction of the tool with its environment is changed. Situated design computing has the capacity to be the basis of computational models of designing that more closely account for the observed behavior of designers. With situated computing tools that learn from their experience and apply what was learned within both life and new situations can be produced (Oero, 2002). A computational system of Situated Learning in Design (SLiD) (Orloff, 2008) was developed to simulate how design knowledge is learned in relation to its situation, how design situations are constructed and altered over time in response to changes taking place in the design environment. Situated learning is based on the notion that knowledge is more useful if it is learned in relation to its immediate and active context, i.e. its situation, and less useful when it is learned out of context. The usefulness of design knowledge is its potential to help designers to solve a problem in a new and unexpected situation.

7. AN APPROACH TO NEW GENERATIONS OF CAAD: WAYS TO A BETTER CAAD FUTURE

■ Based on the recent emerged developments of CAAD, one should expect that the full support to architectural designing requires using computers effectively at the early stages of the design process by transferring the computer into an intelligent and creative medium. A medium that is created by automatically discovering new ideas as the designer moves and acts within it. The creative nature of the architectural designing encourages that role from CAAD systems. The computer can be used as a "metaphoric machine" (Assouline, 1999), means of metaphoric thinking (Van Driel, 1995) and direct design using virtual environments. Computers can be used as a "metaphoric machine" and can serve a superior role in the process of creation, taking the role of the generator of classes. The most important architectural potentials of the new mediation techniques include expansion of spatial imagination, radical break with a hierarchical design approach, and introduction of different disciplines into the design process, relating the design to its final execution. Furthermore is the use of computers for direct design within 3D virtual environments. Architects are often engage with the present metaphoric existing means and act in real time. Architectural designing in virtual environments has the potential of achieving direct manipulation with virtual forms and objects.

■ The proposed approach to new generations of CAAD aims to provide a better CAAD future for architectural researchers, educators and professional demands the elaboration of new methods of using the computer at the early stages of the design process. Using computers in architectural design should not be limited to generating

Figure 6: Section H bounded in red.

The high levels of correspondence might be the result of closer match to student's interests. Paragraph F introduces a methodological approach to the development of design aids. Paragraph H refers to future trends in computational environments in architecture. The group may have either previous knowledge or great interest in topics covered by paragraphs F and H. Therefore this results a higher level of confidence about the understanding of the topics covered in the study document.

To evaluate the importance of previous knowledge in the perceived concept importance between teachers and students, we developed a scoring scheme to measure the distance between known and unknown elements highlighted by the students. The intention was to have a mapping of the overall level of comprehension of the text document for comparison.

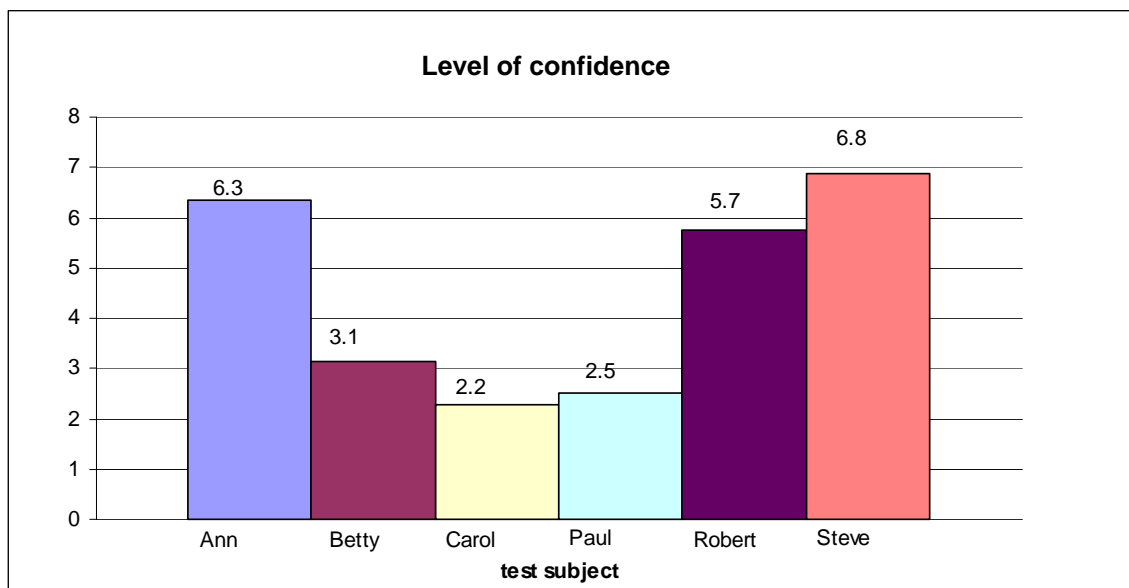


Figure 7: The level of confidence of all test subjects.

The highest level of confidence was produced by the post doctoral fellow Steve. The lowest confidence level was produced by Carol who was a first year PhD student.

The second part of our study analyzed the level of correspondence between the highlights marked by the students and the instructor. We identified areas of the document in which at least five out of six of the test subjects obtained the maximum score possible. Their perceived importance of the concepts match the instructor's perception.

During the study we identified six areas with high levels of correspondence. It is difficult to identify morphological similarities between these six areas. However, similar to what we detected during the evaluation of the data for the level of confidence scoring, the word count for these paragraphs averaged 229.3 words. Two out of six of these areas are preceded by graphical components and 4 out of 6 of them are placed at the beginning of a section. Only one of them is at the end of the section. In this case it is immediately preceded by two graphical components.

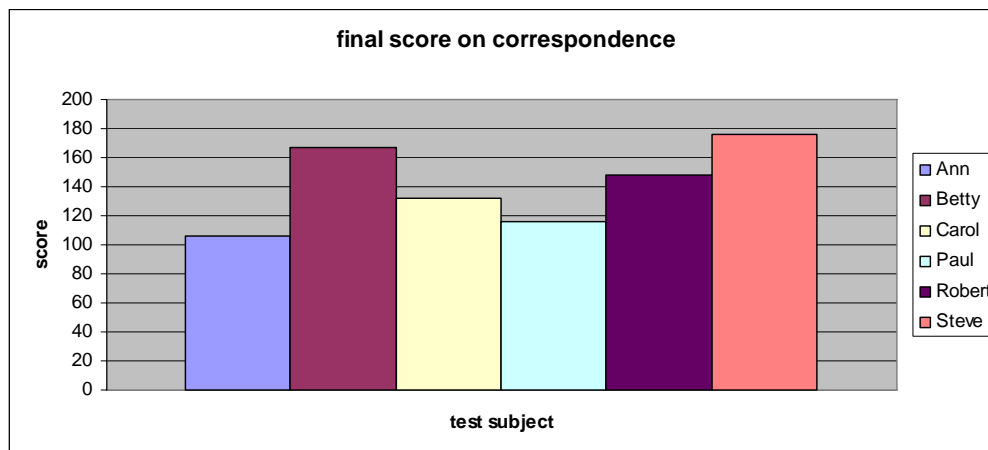


Figure 8: The scores of correspondence on all the test subjects.

The final correspondence score is the addition of all individual scores. The scoring scheme measures the proximity of marking between students and the teacher. The background information provided by the students seems to confirm the pattern produced by the metrics. The highest score (176) was produced by the doctoral fellow (Steve).

3. RELATED WORK AND DISCUSSION

3.1. RELATED WORK

Hsien-Hui Tang (2006) has conducted semester long protocol studies on the level of shared understanding between instructors and students in the studio conversations. Tang's work includes protocol analysis, questionnaires, and ethnographic observations. During the protocol analysis, studio conversations between different students and the same instructor were analyzed to compare their understanding of each other. The students and the instructor were requested to mark the important sentences from the transcripts of the recorded conversation. The sentences marked by both the students and the instructor indicated mutual understanding. The percentages of mutual understanding of the conversations of different students were compared. Better mutual understanding seems to correlate to better grades. However, further studio observations were suggested to investigate the correlations between student grades and their understandings of studio conversations. Tang's work analyzed the level of understanding between the instructors and the students in verbal communication in a studio setting. Our study however is interested in the

comprehension level of study documents, and the impact that education in reading and writing might have in the level of comprehension of these texts.

3.2. DISCUSSION AND FUTURE WORK

The data collected by the study showed that students' expertise of the subject matter is displayed as their comprehension level, and that the markings are in direct correspondence to these levels. The test subject who consistently performed at the highest level is the post doctoral fellow, Steve. The level of performance might be the result of his academic level. It is possible that in his academic career he would have developed a strategy on how to extract information from these documents.

The metrics also helps us identify students who produced least amount of highlights but obtained good results at the level of correspondence (Fig 9). Robert received the best score (Fig 10). He has worked with the instructor for a number of years. It seems that his document reviewing behavior pattern might be influenced by years of shared experience with the instructor. This student not only highlighted the same concepts as the instructor, but he only highlighted those particular text elements, reflecting a high level of correspondence at the behavioral level between him and the instructor. It is worth noting that Robert has the second highest score (148) from our group even though he is a first year PhD student.

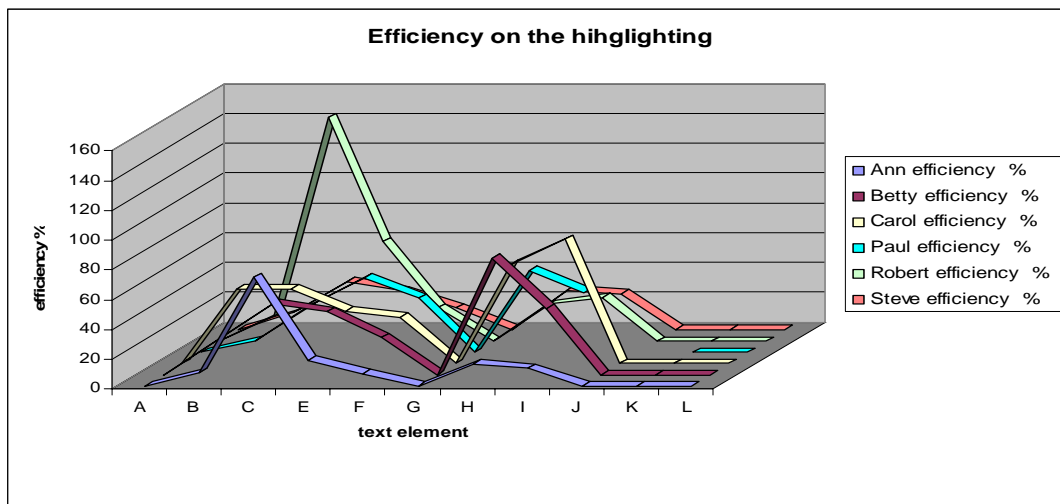


Figure 9: Shows the scores of efficiency in highlighting.

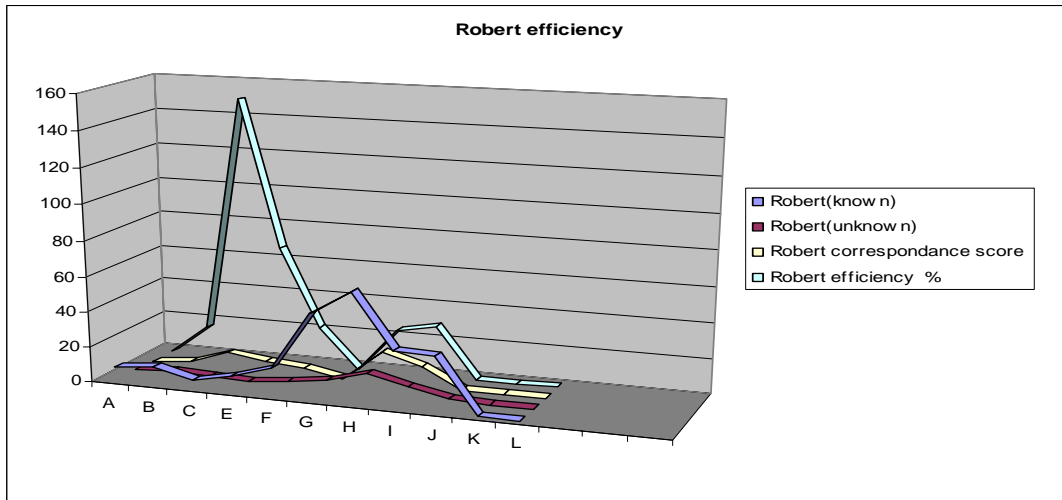


Figure10: Robert's scores of efficiency in highlighting.

Future research would be to further investigate the impacts of the organizational structure of the document on how people perceive the importance of the concepts. It seems that the proximity of supporting elements such as graphical components might increase the comprehension level.

The next step of our research would be to engage with a larger groups of students with different academic backgrounds. We would like to investigate how highlighting behavior evolves over time to verify if students improve their comprehension level of study texts after reading many different documents in a semester.

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