DIGITAL CHARRETTE: A WEB BASED TOOL TO SUPPLEMENT
THE ADMISSION PROCEDURE TO GRADUATE
ARCHITECTURAL DEGREE PROGRAMS

A Thesis
by
KAMESHWARI VISWANADHA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2001

Major Subject: Architecture
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ABSTRACT

Digital Charrette: A Web Based Tool to Supplement the Admission Procedure to Graduate Architectural Degree Programs. (December 2001)
Kameshwari Viswanadha, B.Arch., University of Mumbai (India)
Chair of Advisory Committee: Dr. Guillermo Vasquez de Velasco

The NAAB (National Architectural Accrediting Board), as an evaluator of architectural education in the United States, has established both graduate architectural curriculum criteria and student performance criteria expected to be fulfilled by the student at the time of graduation. To fulfill these standards set by the NAAB, the graduate selection committees of architecture schools require the ability to predict graduate design studio performance of the applicants. Also, the high percentage of international applicants suggests the necessity of a standardized evaluation tool.

This research presents a standardized web based testing environment titled ‘Digital Charrette’ that would contribute toward the fair evaluation of applicants to graduate architectural degree programs. Spatial ability is related to design and visualization skills, a part of the NAAB criteria, and is also associated with design studio performance of architecture students. The Digital Charrette is a VRML environment within which spatial exercises are administered. It is designed to supplement the current admission procedure and would enable the selection of students with a greater potential to perform well in graduate architectural design studios. This research is also an attempt to understand the implications of using virtual three-dimensional environments for such testing purposes. The ability of this web based tool to predict student performance in architectural design studios is investigated. Finally, user reactions to testing in a virtual three-dimensional environment and timed tasks are included in this study.
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CHAPTER 1

INTRODUCTION

This research explores the possibility of accurately establishing the potential of applicants seeking graduate admission to architecture schools. The effectiveness of using three-dimensional virtual environments to test spatial ability of these applicants is investigated in this study.

The NAAB (National Architectural Accrediting Board) in the United States serves as a provider of architectural education evaluation services. NAAB has established certain criteria expected to be fulfilled by both the professional architecture graduate degree curriculum and mastered by the architecture students at the time of their graduation. Analysis of the professional degree curriculum criteria and the student performance criteria established by the NAAB brings to light the necessity of establishing the applicant’s spatial ability before being accepted into the graduate architectural program in the United States (NAAB, founded in 1940).

Spatial ability is the capability of visualizing in three dimensions, i.e. to ascertain the relations of objects in space, to determine shapes and sizes, to mentally manipulate and turn objects, and, to visualize the effects of putting objects together (Satalich, 1997).

This spatial ability is important among architecture students since the architectural profession involves aesthetically modeling three-dimensional space to fit the client’s brief. Architects are expected to be able to use their skills and knowledge to design effectively, and also present their three-dimensional ideas efficiently.

This thesis follows the style and format of the Journal of Architectural Planning and Research.
The current admission procedure to graduate architectural programs consists of two parts. Part one involves evaluation of their undergraduate GPA, GRE scores, TOEFL scores, official transcripts, and financial status. Part two includes assessment of letters of recommendation, statement of purpose and design portfolio (Admission requirements for Texas A&M University).

Though these two parts in combination are the main contributors to the admission decisions made by the graduate committee, there are certain limitations to these criteria; e.g. the score on an international applicant’s GRE exam may be misleading if English is not of common use in their geographic location.

To overcome such limitations of the current admission procedure, this research endeavors to develop a standardized model named ‘Digital Charrette’, a web-based three-dimensional testing environment to supplement the current graduate admission procedure.

The major issues addressed in this research include:

- How do digital three-dimensional and web-based environments contribute towards testing the spatial ability of architecture students?
- What are the user reactions to testing in such an environment that requires dynamic manipulation of spatial representations?
- Is the developed model a valid predictor of design studio performances?

The Digital Charrette was developed using VRML and JavaScript, and was tested with a group of students from the College of Architecture, Texas A&M University, to understand the performance of the developed model in relation to the concerns listed above. Testing on students who were representative of the target population was carried out with the approval of Institutional Review Board, TAMU.

The hypothesis that there would be a positive relationship between performance on the Digital Charrette and design studio grades was proved true by the analysis of testing
results. There was a positive correlation between the student’s design studio grade and their performance on the Digital Charrette; hence suggesting that the Digital Charrette would be a valid predictor of the graduate applicant’s design studio performance. The qualitative responses of the test takers revealed that a greater percentage of the test-takers reacted positively to the Digital Charrette, and considered this tool a valid predictor of their spatial skills.

This thesis includes a discussion of the context of this research, design, development, evaluation of the model, and finally understanding how the conclusion relates to the proposed hypothesis. This thesis is divided into the following chapters:

- Chapter II emphasizes the need for this research, outlining the limitations of the current admission procedures. This is based on a discussion of the NAAB criteria for architecture schools and skills of graduate architecture students.
- Chapter III presents the research objectives and hypothesis, and discusses the importance of this research.
- Chapter IV discusses spatial ability in detail. It includes a classification of spatial ability, established methods of evaluation of spatial ability, and typical tests of spatial ability.
- Chapter V is a discussion on web based testing, and how it compares to other forms of testing; computer based testing, in particular.
- Chapter VI presents virtual environments and their relevance to the evaluation of spatial ability.
- Chapter VII enumerates technical details of virtual environments, relevant to the development of the Digital Charrette.
- Chapter VIII explains the task design considerations, interface and interaction concerns for the development of the Digital Charrette. It additionally specifies the design limitations of the developed model.
• Chapter IX is an evaluation of the developed prototype of the Digital Charrette. The evaluation discusses the study population, the process of testing the model, user reactions to the developed model and statistics of the test results. It also lists limitations of the testing phase of this research.

• Chapter X proposes possibilities for future work based on the pre-testing research and insights gained from the evaluation of the Digital Charrette.

• Chapter XI is a summation of this research and presents conclusions derived from the design and evaluation of the Digital Charrette.
CHAPTER II

NEED FOR RESEARCH

This chapter focuses on establishing the problem definition and context. The analysis of NAAB criteria for architecture schools and skills of graduate architecture students throws light on the limitations of the current admission procedures. This chapter includes:

A. Problem context:
   i. Architecture schools and graduate degree courses
   ii. NAAB criteria for architecture schools and student performance criteria

B. Analysis of contextual elements that lead to development of the Digital Charrette:
   i. Analysis of NAAB criteria and graduate applicant potential
   ii. Current admission procedures and limitations
   iii. Virtual Environments: Possible solution to supplement current admission procedures
   iv. Digital Charrette

A. Problem context

i. Architecture schools and graduate degree courses

NAAB: The NAAB has been selected by the National Council of Architectural Registration Boards (NCARB) to serve as a provider of architectural education evaluation services. Graduate studies in architecture schools are divided into the ‘Master of Architecture’ and the ‘Master of Science in Architecture’ programs.

The mission of graduate education at NAAB (National Architectural Accrediting Board) accredited architecture schools in the United States is to produce technically competent individuals, and critical thinkers who are capable of defining multiple career paths within a changing societal context.
**Professional graduate degree:** Admission to the two year ‘Master of Architecture’ professional degree program is open to applicants who have completed a four-year Bachelor degree with a major in architectural studies or any other similar pre-professional degree from a NAAB accredited institution. Students with undergraduate degrees in fields unrelated to architectural studies are admitted to a 3+ year Master of Architecture.

**Non-professional graduate degree:** The ‘Master of Science in architecture’, a non-professional degree program is for students with a previous NAAB accredited professional degree in architecture (5-6 years), wishing to pursue advanced study and research.

![Diagram](image.png)

**FIGURE 1.** The professional and non-professional programs at the graduate level offered by institutions with NAAB accreditation
The above discussion is based on the ‘4+2 roundtable schools of architecture’, a group of eight schools of architecture with similar curricular structures. This research specifically addresses the two-year ‘Master of Architecture’ professional degree program (Admission requirements for Texas A&M University).

ii. **NAAB criteria for architecture schools and student performance criteria**
NAAB has established certain criteria expected to be fulfilled by both the professional architecture degree curriculum and the students at the time of their graduation.

The professional degree program in architecture as described by the NAAB has three components: General Studies, Professional Studies and Electives. Professional Studies and Electives include courses that are to be incorporated into the curriculum. However including courses related to General Studies within the curriculum is optional.

The student performance criteria established by the NAAB require that the program must ensure that all its graduates possess the skills and knowledge defined by the curriculum criteria in three levels of accomplishment:

- Awareness: familiarity with specific information
- Understanding: assimilation and comprehension of information
- Ability: skill in relating specific information to the accomplishment of tasks

These levels of accomplishment are expected in curricular areas that could be grouped under:

- Design and visualization skills
- Technical skills
- Communication skills
- Humanities
- Professional Practice

Analysis of the professional degree curriculum criteria and the student performance criteria at the time of graduation throws light on an anomaly. Though it is not mandatory in the graduate curriculum criteria to include courses that would help the development of design and visualization skills, the same skills are expected of the student at the time of graduation, as a part of the student performance criteria.

Upon graduation, usually in a two years period, the students are expected to satisfy the NAAB performance criteria. This creates the necessity of establishing the student’s design and visualization capability, before they are granted admission to the graduate program.

FIGURE 2. The NAAB sets criteria to be fulfilled by both the professional degree curriculum and the graduate architecture students at the time of their graduation.
B. Analysis of contextual elements that lead to development of the Digital Charrette

i. Analysis of NAAB criteria and graduate applicant potential

As per the analyzed grouping of the NAAB criteria, the design and visualization criteria include the following skills:

- Formal Ordering Systems
- Graphic Skills
- Critical Thinking Skills
- Fundamental Design Skills

One of the underlying contributing factors for all the skills described above is spatial ability, the ability of visualizing in three dimensions, which differentiates architecture students from all other students.

Spatial ability in architecture students is an important concern as their skills include perceiving un-built spaces. Spatial ability is most commonly known to consist of spatial visualization factor, spatial orientation factor (Stringer, 1971), and spatial relations factor.

Chapter IV of this thesis is a detail study of spatial ability and its assessment.
FIGURE 3. Spatial ability is one of the binding factors of all the skills listed under the Design and Visualization skills described by the student performance criteria set by the NAAB.

ii. Current admission procedures and limitations

Admission to the graduate schools of architecture is a two-part process:

**Part One:** The first part includes approval of the Graduate School committee of the university, and the second part involves the approval of the School of Architecture. The Graduate school in most universities checks that the student satisfies the minimum graduate student academic requirements of the school, i.e.- GPA, GRE scores, TOEFL scores, official transcripts & financial status.
Part Two: The School of Architecture graduate admission committee conducts a detailed evaluation procedure where they also assess the design portfolio, letters of recommendation and statement of purpose. Most of the architecture schools clarify in their application catalogues that they are specifically evaluating visual creative work of the applicants in the design portfolios.

Limitations to the current admission criteria are listed below

- Regional standards of evaluation: Because of the geographical and cultural diversity of the applicants, letters of recommendation and official transcripts are not adequate criteria to evaluate the applicants. They would have been judged as per the local acceptable standards, which cannot be expected to be uniform.

- Native Language of the applicants: Though GRE follows a standardized computer-based testing system; these scores could be misleading when the applicant’s native language is not English, particularly because of the verbal scores.

- Issues of dubious authorship: Design portfolios, considered the best evaluators of a student’s potential are now subject to questionable authorship due to a rise in the number of professional firms specializing in creating these for architecture students.

iii. Virtual Environments: Possible solution to supplement current admission procedures
An ideal supplement to the current admission procedure would be one which:
- Is universally applicable and standardized
- Has the ability to evaluate the spatial ability of the applicant
- Does not require the knowledge of specific software
Virtual environments, within the scope of this research, refer to three-dimensional environments accessible within a web browser, and created using VRML as a tool. These environments are ideal to test the spatial ability of the applicants since they satisfy all the criteria listed above for an ideal supplementary tool to aid the graduate admission procedure. Virtual environments are discussed in detail in Chapter VI.

iv. ‘Digital Charrette’

To overcome the limitations of the current admission procedure to graduate architecture degree schools listed above, this research involves determining a standardized platform to supplement the admission procedure. This conceived supplementary tool is referred to in this thesis as the ‘Digital Charrette’. The meaning of the word ‘charrette’ denotes a final, intensive effort to finish a project before a deadline; thus the title ‘Digital Charrette’ captures the spirit of the timed spatial exercises in a virtual environment. The developed prototype of the Digital Charrette is a web-based environment that includes a set of spatial exercises.

Features of the ‘Digital Charrette’:

- Seeks to test spatial ability
- Web-based prototype (only requires VRML and JavaScript enabled browser to run on any machine connected to the Internet)
- Does not require any software expertise or mastery over a particular language
- Negates the geographic barriers between the diverse locations of the applicants
If developed further, can be administered similar to the GRE and TOEFL computer-based exams at international centers. The identity of the test-taker could be confirmed, and the issue of dubious authorship that comes into question when dealing with design portfolios would be solved.

These features would help the Digital Charrette overcome most of the limitations of the current graduate applicant assessment techniques followed by architecture schools.
CHAPTER III

IMPORTANCE OF RESEARCH

This chapter introduces the research objectives and hypothesis, and discusses the potential benefits of this research under the following titles:

A. Research objectives
B. Hypothesis
C. Possible benefits of research

A. Research objectives

The purpose of this research is to prototype at small scale, a web-based assessment tool to evaluate the spatial ability of graduate applicants to architecture schools.

The objectives of this research are:

- To understand the extent of influence of the applicant’s previous experience with computers, Internet and digital games and their success on the Digital Charrette tasks.

- To examine if this medium of testing in a virtual environment proves to be a valid predictor of the applicant’s prospective performance in graduate design studios.

- To understand if the medium of timed exercises in a virtual environment increases the inhibition/motivation of the applicants to participate in an unhesitant play and experiment during the testing process.
To explore how regular tests of spatial ability can be manipulated to create exercises that are relevant to architecture school applicants.

B. Hypothesis

*Scores of the applicants on the developed testing model ‘Digital Charrette’ are reflected in their performance in graduate design studios.*

![Diagram](image)

FIGURE 4. The hypothesis for this research suggests that scores on the Digital Charrette are reflected in their performance in graduate design studios.

C. Possible benefits of research

This project is of importance to architectural faculty and students seeking admission to graduate programs in architecture. This research would also be of interest to policymakers, educators and test developers who are charged with improving the measurement of student achievement, since spatial ability and web-based testing are universal concerns.

This research is important due to the following reasons:

- As stated earlier, it has been defined as a unique ability of architecture students to be able to visualize and think in the third dimension (Stringer, 1971). Hence, the capability of the testing model to accurately test the spatial visualization ability of the potential graduate students will be significant.
- It has also been proved that scores on spatial skills are valid predictors of design studio performances (Stringer, 1971).

- Since research has proved that training can positively affect spatial ability, e.g. Teaching ‘manipulatives’ in mathematics has been found to positively impact spatial ability (Melancon, 1994); such strict admission procedures will lay stress upon the undergraduate academic curriculum to develop the spatial ability of students.

- Besides aiding the admission procedure, this testing model may also help to identify those students who may be at a risk of lower grades during their early design coursework.

- Architectural colleges would be better equipped to satisfy the NAAB criteria for student performance, if they are able to identify and admit students with greater potential for graduate design coursework.

- Virtual environments have been used in other fields for testing of spatial ability and research conclusions have proven to be positive, both in the prediction ability of the environment and the user reactions. Extending this to the field of architecture would help increase the knowledge base for using virtual environments in education.

- Organizations such as ‘Architecture in Education’ could use a simplified version of the Digital Charrette in their efforts to introduce architectural education to schoolchildren as a part of vocational guidance (Architecture in Education, established in 1981).
CHAPTER IV

SPATIAL ABILITY

This chapter includes a discussion of the classification of spatial ability, established methods of evaluation of spatial ability, description and key features of typical tests of spatial ability and related research. It includes:

A. Importance of the assessment of spatial ability
B. Spatial ability factors
C. Research related to spatial ability
D. Evaluation of spatial ability
E. Typical tests of spatial ability
F. Spatial ability tests for architecture students

A. Importance of the assessment of spatial ability

Space may be defined as a boundless three-dimensional extent in which objects and events occur, and have relative position and direction. Thus, time may also constitute a factor in this extent, though not included in the scope of this research.

Spatial ability is the ability to judge the relations of objects in space, to judge shapes and sizes, to mentally manipulate objects, to visualize the effects of putting objects together, and to mentally reorient objects.

Research in psychology has extensively recognized spatial ability as a factor contributing to success in mathematics, natural sciences, engineering, architecture, and other fields of study (John Hopkins University, Center for Talented Youth).

New technologies and techniques such as computer graphics, scientific visualization, and medical imaging, require higher levels of spatial ability. Thus, spatial ability will become increasingly more important as we move into an ever
more technology-driven world. Individuals with highly developed spatial ability, those who can see patterns in what appears to be confusion to others, will become more in demand in most fields. In the field of architecture, this ability gains further importance, since an architect uses this ability to perceive patterns and relations in un-built spaces; and a lot of resources are invested into achievement of this vision.

B. Spatial Ability Factors
Clements and Battista (1992) define spatial ability as consisting of "cognitive processes by which mental representations for spatial objects, relationships, and transformations are constructed and manipulated." Linn and Peterson (1985) similarly state that spatial reasoning "refers to skill in representing, transforming, generating, and recalling symbolic, nonlinguistic information" (Satalich, 1997). Though there are various revisions to the definition of spatial ability, there is a general consensus that spatial ability is dependent upon multiple factors.

The three major factors of spatial ability that are commonly addressed are: spatial orientation, spatial visualization and spatial relations

- **Spatial orientation** involves the ability to mentally move or transform stimuli, while retaining their relationships. Spatial orientation also involves the mental manipulation of an object using oneself for reference.
- **Spatial visualization** is the ability by which a person manipulates the relationships within an object, imagines movement or displacement of internal parts of a spatial configuration.
- **Spatial relations**, the third major factor, consists of the ability to imagine how an object will align from different perspectives or recognizing an object from different angles (Satalich, 1997).
The lack of a universally accepted definition of spatial ability may be due to the lack of replicability of the factor structures found when several tests are used (Voyer, Voyer and Bryden, 1995).

Spatial skills are proven to be integrated into the performance of complex realistic tasks, such as problem solving and design in both everyday tasks and profession-related ones. Researchers have identified over 86 different careers where spatial visualization skills are essential for success.

Several other terms have been identified as related to spatial ability; few of which are listed below:

- **Visual/ Spatial memory** is the ability to remember spatial information (Leitheiser, Bob & Munro, 1995)
- **Spatial representation** refers to either two-dimensional or three-dimensional modes of representing spatial information/ relations.
- **Spatial cognition** is information processing as applied to space and spatial relations (Wickens, 1992). It is also defined as how human beings deal with issues concerning relations in space, navigation and wayfinding.
- **Spatial competence, spatial reasoning** and **spatial skills** are other terms used to refer to spatial ability.

**C. Research related to spatial ability**

J. Galen Buckwalter and others in the paper “The use of Virtual Reality (VR) in the assessment of spatial skills” suggest that tests of spatial rotation ability that are administered in a VR environment may prove to be a superior method of assessing spatial cognition. The use of VR in the assessment allows quantification of multiple characteristics of the stimuli. Their pilot studies show that testing in the virtual environment negated the disadvantage that the female gender have on the pen and paper tests of spatial cognition. The researchers
consider the ability of three-dimensional testing and possibility of having complete control over the stimuli presented to be some of the advantages of testing using VR (Buckwalter and others, 1999).

Gagnon (1985) studied the relationship between spatial skills and video games. It was found that scores on a two-dimensional spatial test were related to scores on a two-dimensional video game while spatial visualization scores (three-dimensional test) were related to scores for a three-dimensional game. Eye-hand coordination was found to be unrelated to video scores or spatial test scores. Male subjects tested higher on spatial tests than female subjects but the latter were able to significantly improve their spatial test scores after video game practice. Similar to another study by Egan and Gomez, a negative correlation was found between age and performance (Leitheiser, Bob and Munro, 1995).

Despite findings that males are superior to females in spatial ability have found that genetic factors are not the cause of these differences.

With proper instruction, females can perform as well as males at creative visual thinking and problems requiring spatial ability. These findings suggest a need for a better understanding of processes involved in the development of spatial visualization skills (Melancon, 1994). It has also been found that spatial abilities of both males and females improve as they become more involved with such tasks as model building, working with 3-dimensional objects, and solving spatial visualization problems. Educators can help teach these important skills (Melancon, 1994).

Researchers at University of California, Santa Barbara, are trying to find solutions to the following problems related to spatial ability, which are also issues that are related to the current research:
- Does the measurement of environmental spatial abilities differ as a function of whether static or dynamic materials are involved? This might be true in either of two ways:
  - A test may be presented in a static or dynamic format (e.g., drawings vs. computer animations)
  - A test presented in a static format may or may not require dynamic manipulation of spatial representations.

- Do spatial abilities differ as a function of the size of the space involved?

- Does the measurement of environmental spatial abilities differ as a function of whether a person is imagining the space being tested or is actually located in that space? (Research Group, Department of Psychology, UCSB)

D. Evaluation of spatial ability

The America Psychological Association (APA) provides guidance to find specific types of psychological tests (includes spatial ability tests). Tests in Print (TIP), the Mental Measurements Yearbook (MMY), Tests, and Test Critiques are considered the four most useful and popular references. Most of these however refer to paper and pencil tests.

The John Hopkins Institute is one of the establishments that use computer-based testing of spatial ability. The following questions, which form an introduction to their ‘Spatial Tests Battery’ that determine spatial intelligence throw light on the design aspects of these tests (John Hopkins University, Center for Talented Youth):

- Do you think you have a special talent for visualizing how objects look from different angles?
- Can you easily manipulate images in space?
• Do you seem to have a knack for seeing how complex systems operate?
• Are you able to easily remember faces, objects, or interesting designs?
• Do you prefer visual images and graphic displays to text?

E. Typical tests of spatial ability

The most common methods of assessment of spatial ability include in standardized spatial test batteries are:
- Surface development
- Block rotation
- Perspectives
- Visual memory

Though these names correspond to the ‘Spatial Tests Battery’ of the John Hopkins Institute, the same tests are commonly found in other spatial ability testing modules, and slightly vary in design and naming convention, e.g. Block rotation may be referred to as Cube rotation. Some tests also include a practice or study phase before administering the actual test. In solving the tasks in a spatial test, several processes may be used simultaneously, and each test though tending towards one of the factors of spatial ability discussed above, need not necessarily involve the testing of purely one factor (Sjolinder, 1998).

These tests are described below to help understand the nature of the tasks involved in these tests, and, how they relate to the definition of spatial ability (John Hopkins University, Center for Talented Youth):

**Surface development test:** The test taker is presented with a two-dimensional folding diagram in the surface development test, and is asked to determine which of the lettered edges on the solid match with the numbered edges of the diagram. In other words, you will see irregular, flat shapes, and three-dimensional objects created by folding these shapes; it will be your task to find out the corresponding edges of the flat shapes and edges of the boxes. There could be letters or
additional clues to help make this connection, or add another dimension to the test, when they are also shuffled. This test concentrates on the visualization factor of spatial ability (Eisenberg, 1996).

**Block rotation test:** In the *block rotation test*, the test taker is presented with three-dimensional blocks of different shapes; either cubes, cylinders, or other irregular objects. Though there are a few variations to the actual design of the alternatives for this test, the most common example is one in which a model block is given. The task is to identify from the given alternatives ones which are the same as the model block when rotated in space.

**Perspectives test:** In the *perspectives test*, one view of a set of objects is presented to the user. Most of these tests use all objects of similar shape and size. Therefore, the objects in the foreground appear larger; and the other objects in the background appear smaller. Depending on the perspective, some objects may be hidden behind others. One view of this arrangement is presented to the viewer. Another view of the same arrangement of objects is presented to the test taker, whose task is to determine the direction from which the arrangement is viewed in this second perspective.

**Visual memory test:** In the *visual memory test*, you will have to memorize irregular shapes and objects, parts of which may be either blackened or made distinguishable in some other way. The actual number of these shapes varies, and the time interval after which the second part of the test is administered varies. The second part of the test consists of identifying these shapes or objects in sets of similar figures.

**F. Spatial ability tests for architecture students:**

The standard tests for the assessment of spatial ability are generic. They are designed for a target audience belonging to a wide cross-section of backgrounds,
knowledge, skill levels and age. These tests are currently administered either as paper and pencil-based tests or computer-based two-dimensional tests. These methods of evaluation would not be able to overcome the limitations enumerated in Chapter II regarding the current admission procedure to graduate programs in architecture schools.

To overcome limitations like regional standards of evaluation and international accessibility, the Digital Charrette was conceived as a set of spatial tasks in a web-based three-dimensional environment.

The study population for this research is defined as graduate applicants to architecture degree programs. Chapter IX elaborates on the study population and other evaluation details.

It was considered important to vary the complexity of the tasks in comparison to the standard spatial ability tasks mentioned above, and also to introduce an architectural design context to the tasks involved, wherever possible. The design of each of the Digital Charrette tasks is further explained in Chapter VIII of this thesis.
CHAPTER V

WEB BASED TESTING

This chapter discusses the relevance of web based testing, and compares it with computer based testing. It also includes a discussion of the advantages and disadvantages of web based testing under:

A. Web Based Testing (WBT)
   i. Other types of testing
   ii. Disadvantages of other types of testing
   iii. Advantages of WBT

B. Computer based testing v/s WBT

C. WBT concerns

D. WBT authoring tools and Digital Charrette

A. Web based testing (WBT)

The term ‘Web based testing’ refers to using the World Wide Web to conduct tests or assessment of learners. This might be evaluation for supplementing classroom training, assessing distance education learners or as in the present research case, for assessment of skills of either prospective students or employees.

i. Other types of testing (Hamilton, Klein and Lorie, 2000)

- **Paper and pencil tests**: These have been the traditional ways of administering most kinds of tests, and are still very popular. However these tests limit the kind of skills that can be measured.
- **Hands-on testing**: Though these tests are able to assess skills better than paper and pencil tests, they can be very expensive and research has proved that they do not necessarily measure the constructs that their developers intended.
- **Computer based testing**: This type of testing is the closest in nature to web-based testing. Computer based testing will be discussed in detail in the following section.

ii. **Disadvantages of traditional testing methods**
- There is a time lag between test administration and score reporting.
- Traditional testing methods are subject to geographic and temporal limitations. If the geographic limitations are eliminated by mail-in tests, then the identity of the test taker may be questionable.
- The traditional testing methods are also limited in their ability (Hamilton, Klein and Lorie, 2000) to measure skills, e.g. Gender-based differences found in paper and pencil tests of spatial ability.

iii. **Advantages of WBT** (Hamilton, Klein and Lorie, 2000)
- **High Availability and convenience**: Test takers only need a web browser and a web connection. Thus the geographic and temporal restrictions associated with other types of testing are negated.
- **No Equipment Maintenance**: There are certain agencies that host Web-based Testing modules, which even reduces the cost of having in-house maintenance of Web Servers or other software/equipment. Also, this is an inexpensive way of worldwide test administration.
- **Online Administration**: With the easy to use online administration you may use a browser to control who has permission to take a test.
- **Scalability**: Depending upon the Web Server capabilities, multiple students can take the test at the same time.
- **Time**: The main advantage of WBT is the time factor, which is drastically reduced when administering and scoring the test as compared to other traditional models of testing.
B. Computer based testing (CBT) v/s WBT

Though WBT has numerous advantages, there could be situations in which computer based testing is preferred to WBT; e.g.,

- If the test requires trained supervision or specialized software, CBT may be a better option.
- If the expected test-taker population is limited, it may be economical to use CBT.
- If the test evaluation objectives also include observation of the reactions and reservations of the test-takers, CBT administered in a controlled environment may be beneficial.

However, CBT also has certain limitations that are overcome by WBT, i.e.

- If the expected test taker audience is large, it would be very expensive to make CBT available on a number of systems.
- Also, CBT is limiting since it doesn’t work on the asynchrony principle (Roever, 2001) as WBT, i.e. access times related to centers where CBT is administered are limited.

C. WBT concerns

*A Comparative Analysis of Web-Based Testing and Evaluation Systems* by E. J. Gibson and others suggests following areas of concern for evaluation systems (Gibson, Brewer and Dholakia, 1996):

- Testing functionality
- Tracking capabilities
- Grading capabilities
- Implementation issues
- Security issues

The development stages of a WBT module could be listed as:

- Pre-test development survey
- Test development
- Test administration
- Test scoring
- Recording test results
- Feedback

WBT as an assessment tool written in the language of the web (Roever, 2001) can be designed to have advanced features beyond the scope of this research, i.e.
- A high level of interactive assessment can be incorporated into WBT with web-based programming whereby the student is given immediate feedback
- Adaptive testing may be introduced through WBT where successive questions are picked from a question bank after evaluation of each response of the test taker.
- It is possible to use question banks from which questions are randomly picked and organized to create unique tests.
- The test taker’s response could be immediately evaluated and feedback may be issued at every stage, depending upon the objectives of test designer.
- Multiple users could take the same test at the same time or within the same virtual testing environment, depending upon the server capabilities.
- The test taker’s responses could be tracked and used to establish user patterns for design improvements of the tests.

The limitations of WBT are listed below:
- WBT is subject to technical problems associated with bandwidth limitations, server failure and browser incompatibility.
- Human contact is almost negligible in WBT because of which user reactions cannot be observed, though web cams can overcome this to a certain extent.
- If required for a small target population, the time and resources required during the test development phase of WBT may prove to be expensive.
- WBT may cause anxiety amongst test-takers with no prior computer experience.

D. WBT authoring tools and Digital Charrette

There are commercial testing tools and agencies that help to create WBT modules; and also available are authoring tools that use either JavaScript or CGI; e.g. HotPotatoes and WebTest. These are able to create a wide variety of student evaluation exercises, from simple multiple-choice questions to crosswords and puzzles.

Since the current research focuses on development of spatial exercises and proposes to also use the third dimension for testing, it cannot take advantage of these established authoring tools.

The Digital Charrette may be considered as a prototype for web based/ computer based evaluation of architecture students, since it is a three-dimensional environment. This environment if extended to evaluate students during their architectural academic program could be developed to shape a superior testing model, since architectural concerns such as form, hierarchy, composition and scale may be effectively represented and tested in a three-dimensional virtual space. The Digital Charrette is thus an example of customized WBT.
CHAPTER VI

VIRTUAL ENVIRONMENTS

This chapter presents virtual environments in education and their relevance to the evaluation of spatial ability.

A. Virtual environments in Education
B. Research related to Virtual Environments and education in architecture/related fields

A. Virtual environments in Education

Virtual environments are ones that the users perceive as comparable to real world objects and events. This virtual reality is simulated by the use of advanced technologies, including computers and various multimedia peripherals, to create the illusion of real space and objects.

Both immersive virtual environments and VRML worlds accessible within a web browser have been experimented with, as an educational tool, over a wide variety of topics. Stephen Davis in his report discussing virtual realities in education (Davis, 1996) discusses the possible applications to higher education and suggests that they can be divided into three areas:

- A medium to enhance teaching and research
- A new subject of study
- A collaborative space

However this definition does not involve the possibility of using these environments as an effective testing platform.
Virtual environments strongly embody the ‘Constructivist’ learning theory (Smith, 1999), which defines learning as an active process and assimilation of knowledge constructed on past experiences and social/learning context.

Virtual environments are useful in education in the following ways (Eslinger, 1993):
- When it is too expensive or dangerous to train students with actual equipment, virtual environments can be beneficial.
- They can enhance the classroom environment and increase student participation; at the same time they are also able to contribute effectively to distance learning situations.
- They can provide the tools to visualize and manipulate abstract information, thus making it easier to understand various concepts, e.g. Virtual environments can allow participants to experiment with physics concepts such as a virtual physics lab that allows students to control gravity, friction and time.
- They could be multi-user spaces where participants learn by sharing knowledge and observing how others manipulate objects in this virtual space.
- Virtual environments are also useful in training students with disabilities.

In the ‘VR In The Schools’ newsletter published by the East Carolina University Virtual Reality and Education Laboratory, Dr. Veronica Pantelidis gives a list for the reasons to use graphic and text based VR in education (Pantelidis, 1995).

The benefits include that VR:
- Can more accurately illustrate some features and processes by virtue of its three-dimensional nature.
- Allows examination of objects from various views and distances.
- Allows the disabled to participate in an experiment or learning environment
- Allows learner to proceed through an experience at his/her own pace.
- Encourages creativity
- Provides social atmosphere

M. A. Syverson and John Slatin in their paper titled “Evaluating Learning in Virtual Environments” discuss the concept of an online virtual portfolio, to provide qualitative methods of evaluation for such diverse learning environments (Syverson and Slatin, 1995). This allows learners to be evaluated in an environment where the possibilities of expression could be both multi-dimensional and enhanced by multimedia.

B. Research related to Virtual Environments and education in architecture/related fields

- Timothy O’Leary in his paper on “On-Line Learning Environments in Architectural and Construction Education” discusses how new Internet technology including VRML environments could be used to significantly impact education in architecture and construction studies (O’Leary, 1997).

Web technology could be exploited to simulate the site visit experience and provide both visual and text information that can enrich the teaching process through experiential learning. Also, as the design and construction industry moves towards using the Internet in project environments and exchange of information, exposure to emerging web technologies can greatly improve their understanding of a technologically advanced design and construction workplace.

- In their paper titled “3D Finite Element Analysis on the Internet using Java and VRML” by Karthik Ranga and Kurt Gramoll, the authors
describe the development of a model that allows for engineering
design and analysis over the Internet (Ranga and Gramoll, 2000). This
interactive VRML model allows the user to vary the length and height
of the L-shaped beam subjected to a point load and the Java program
computes the 3D stresses in the beam using the finite element method.
Similar models extended to instruction of architecture students could
be very beneficial. Also, 85% of people are proven to be visual
learners, hence when the students are able to witness the changes to
the architectural structural system depending upon the way they
change the sizes and loads would be valuable.

- The paper titled “Virtual Environment Design- Defining a new
direction for architectural education” discusses how architectural
design is intrinsically related to virtual environments and how it
should play an important role in educating VE designers (Bourdakis
and Charitos, 1999). This paper by Vassilis Bourdakis and Dimitrios
Charitos aims at pointing out the need for a new direction within
architectural education, which will lead towards a generation of VE
architects.

This research involves application of virtual environments to testing architecture school
applicants, and uses VRML, a web-based three-dimensional language to develop this
application. Thus, this study involves development of a web-based environment to test
spatial skills of applicants to graduate architectural programs.
CHAPTER VII

DIGITAL CHARRETTE: VIRTUAL TESTING ENVIRONMENT

This chapter enumerates technical details of virtual environments, relevant to the developed prototype of the Digital Charrette.

A. VRML and limitations

B. VRML and JavaScript

A. VRML and limitations

VRML is virtual reality modeling language, the standard authoring tool for virtual reality/interactive three-dimensional worlds on the Internet. VRML files define worlds, which can represent 3D computer-generated graphics, 3D sound, and hypermedia links. The documents have *.wrl extensions that can be viewed by a browser with an appropriate plugin or helper-application.

The viewing of VRML models and navigation through the three-dimensional environment via a VRML plug-in for Web browsers is usually done on a graphics monitor under mouse control. The syntax and data structure of VRML provide an excellent tool for the modeling of functional and interactive three-dimensional worlds that can be transferred into fully immersive viewing systems. VRML is encoded in UTF-8 (Unikey) format, so one can create very detailed 3D scenes using very small files, that can be downloaded quickly, an important concern while dealing with the Web (Bieir, 2000).

Advantages of using VRML for the development of the ‘Digital Charrette’:

- The viewer has complete control of the authored environment, and can navigate through and experience three-dimensional space.
Unlike previous similar research, which used other tools and CAD systems, where the test-taker would first have to master the tool. Using VRML environments, the test-taker can directly start solving the spatial tasks with little practice of VRML player controls. The test-taker can concentrate on the spatial experience, rather than the technical aspects involved in manipulation of the environment. Also, applicants who are familiar with digital games would have been exposed to similar controls and interfaces, where buttons on screen are used to manipulate perceived objects.

Though not exploited within the scope of this research, using VRML also unwraps the possibility of Multi-user testing. This initiates the possibility of collaborative games, whereby the evaluator could also study the applicant’s group dynamics and ability to perform creatively in a collaborative environment.

VRML environments are completely accessible with only a Web browser and deliverable over the Internet. Hence they are globally accessible, and geographical distances of the applicants would not affect their participation. Expensive software need not be present on the user’s computer to be able to access the tasks within the Digital Charrette.

Scripts operate within the VRML browser. The behavior of objects within VRML worlds is controlled using sensor nodes, interpolator nodes and script nodes. These nodes allow creation of dynamic worlds with the possibility of animation, multimedia (sounds and movies), interaction and controlling complex behaviors through scripts.
Limitations of VRML:
- VRML sensors do not support sensing of object-to-object interaction.

- Using script nodes, there is no way for a script to communicate with any external Java code such as an applet or transmit information over a network, except by using External Authoring Interface (EAI). Most browsers support Java as the primary language interface to program to the EAI. Since Java is a complex full-featured programming language, the author of the VRML world would require greater technical expertise.

B. VRML and JavaScript

Complex animation and interactivity that are not possible with VRML sensors and interpolators nodes can be achieved through Script nodes. A Script node is a shell of a node; it has fields, eventIns and eventOuts, but has no actions on its own. Instead, the author of the VRML world can provide custom Script node actions by providing a program script (Ames, Nadeau and dan Moreland, 1996).

JavaScript is a language developed by Netscape Communications that enables one to add animation to Web pages or control activities within a VRML world. Java, a language developed by Sun Microsystems is a full-featured programming language that provides extensive features needed for larger programming objects and that may be used when it is required to transmit data over networks. Though either language could be used to write programs for a Script node (Ames, Nadeau and dan Moreland, 1996), for the purpose of this research, JavaScript was chosen to program the interactivity required for interactivity of the tasks within the Digital Charrette.

The features the VRML browser must provide to a Java or JavaScript program script, classified as part of the language’s API (Application Programming Interface) are (Ames, Nadeau and dan Moreland, 1996):
- Access to the interface fields and eventOuts of the program script’s Script node
- Conversion between VRML’s data types and those of the programming language
- The ability to initialize and shutdown a program script and to respond to incoming events
- Access to the browser to change world content or load a new world

Since the VRML browser allows the above features, JavaScript can be used to both track and evaluate user’s movements in the virtual environment.

JavaScript is used within the Digital Charrette for the following:

- Front-end validation purposes: The test taker cannot enter the Digital Charrette without typing in their first name and last name.
- JavaScript is used to greet the test taker by their first name in the task description screen.
- Timer: A countdown timer displays the time left to complete the current task.
- Task evaluation scripting: JavaScript within the VRML world check the position of the test blocks, and record a win situation when the test taker has manipulated the blocks correctly.
- Transition scripting: Transition screens between the completion of one task and the beginning of the next one display to the test taker their result on the task completed.
CHAPTER VIII

DIGITAL CHARRETTE: DESIGN AND DEVELOPMENT

This chapter explains the task design, interface and interaction design of the Digital Charrette. It also specifies the design limitations of the developed model.

A. Task design and description of each task
   i. Task 1: Identifying viewpoints for a VRML model
   ii. Task 2: Subtractive task
   iii. Task 3: Additive task
   iv. Task 4: Creating positive model with a negative reference

B. Interface and Interaction Design

A. Task Design and description of each task

Task Design: These tasks were designed on the basis of an informal study of various sample tests available on the Internet for testing spatial skills. URLs have been included in Appendix A. These tests are designed to require medium skill level. Within the available timeframe, it was considered important to give equal importance to all three aspects of design: task design, interface and interaction issues and finally implementation of a prototype. Within the scope of this research, considering both the time available for development of the prototype, and the time available for testing the prototype with the target audience, the exercises are designed to be short timed exercises, using the metaphor of games. Please refer to Section B of this chapter for images of the tasks described below:

i. Task 1: Identifying viewpoints for a VRML model

The first task involved examination of an architectural block model (manipulated to increase complexity), and the test taker’s challenge was to identify the viewpoint for each of three given snapshots of the model. These were multiple-choice questions, with four choices for each question. The
first two questions involved identifying the direction from which the view was perceived; the North direction was indicated in the architectural model. The third question involved identifying the relative height of the viewpoint from the ground level, given the value of the highest point in the model. Time allotted for completion of this task is three minutes.

ii. **Task 2: Subtractive task**
The second and third tasks closely resemble regular spatial testing blocks. The second task presents the test taker with a model block and a task block. The test taker’s assignment is to click on all the blocks in the task block that would help transform the block into the model block. Thus this is a subtractive task. The test taker has to take care that no blocks are accidentally clicked while navigating through the virtual space. There is an anchor cube colored differently to help the test takers establish their position in the virtual environment, and to avoid getting lost in virtual space. Time allotted for completion of this task is also three minutes.

iii. **Task 3: Additive task**
The third task also modeled on regular spatial testing exercises involves moving and placing together the given five task blocks so that it is converted into the model block. One of the five task blocks is an immovable anchor block, similar to task two, that helps the test takers get their bearings in the VRML environment. Time allotted for completion of this task is five minutes.

iv. **Task 4: Creating positive model with a negative reference**
The fourth exercise more closely reflects an architectural context, the skills that would be important to the graduate architectural school admissions committee. Also, this was designed to evaluate if there is a difference in the
student performance between tasks that use geometric models similar to regular spatial skill tests and tasks that are customized. This task requires the test taker to use the given blocks to build a positive model of the negative space within the test block. Time allotted for completion of this task is five minutes.

B. Interface and Interaction Design

The student is taken through fourteen screens before they complete their tasks within the Digital Charrette.

**Screen 1:** This is the introduction screen that checks if the test taker has a VRML player for their browser. If the test taker cannot see the four stacked cubes as shown in the figure below, a link to the Cosmo Player website is displayed from where the test taker can download a free Cosmo player.

![FIGURE 5. Checking for a VRML player](image)

**Screen 2:** Once it is confirmed that the test taker has a VRML player installed, he/she is taken to a practice session to learn how to manipulate objects and move through a VRML world. The time spent on the practice session is left to the discretion of the test taker.
Screen 3: This is the Login Screen. The student is prompted to enter their first name and last name, and is also informed of the objectives of this research. A javascript validation function does not allow the user to proceed without typing both their first name and last name.
Screen 4: The constant screen layout that is followed for all the tasks is illustrated. For each of the tasks, there is a header frame that runs horizontally across the screen. The header frame contains a brief description of the task and houses a countdown timer. The rest of the screen is divided into two halves; the left frame contains the test or the model block that is the reference for the test taker. The right frame is the task area within which the test taker is required to solve the designed tasks. Both the left and right frame have individual VRML player controls, to allow greater flexibility to the test taker. This screen also gives a brief explanation to each of the four tasks within the Digital Charrette, greets the player by their first name and wishes them good luck before moving to their first task.

FIGURE 8. Task Description

Screen 5: This is the first task. As described earlier and demonstrated in the figure below, the first task consists of three multiple choice questions related to defining the direction and height of the viewpoint of each of the three snapshots. For each of the tasks, there is a small window that pops up simultaneously while displaying the task. This gives a detail explanation of what is expected of the test taker for the task in question. It describes what is displayed in the left frame, the
right frame and finally, what the test taker’s assignment is. There is a close button that the test taker can use to close the window upon reading the instructions.

FIGURE 9. Task One - Identifying viewpoints for a VRML model

Screen 6: Depending upon whether the task times out or the test taker completes the task, the information of this transition screen changes. It either displays “You finished on time!” or “You didn’t make it”. The test taker then clicks on the arrow to proceed to the next task. Screens 8,10 and 13 would be similar transitions between tasks.

FIGURE 10. Transition screen- Task completed on time or task times out
**Screen 7:** This is task two, a subtractive task as described in the earlier section. Since the aim of the test taker is to replicate the geometry, the given test block is monochromatic except for the purple anchor block, while the task block is composed of multicolored units.

![FIGURE 11. Task 2- Subtractive task](image1)

**Screen 9:** This is task three, an additive task that requires the task taker to move the given blocks and assemble them to resemble the test block within five minutes. The rust colored block is the anchor block.

![FIGURE 12. Task 3- Additive task](image2)
**Screen 11:** This is a demonstration that helps the test taker understand the complexity of task four. Two images in the left frame help understand positive blocks and negative space within the given blocks. An animation in the right frame helps the test taker understand how their task is to assemble the given blocks to create the negative space within the test or model block.

![FIGURE 13. Task 4- Demonstration](image)

**Screen 12:** As explained above, task four expects the test taker to build a positive model after visualizing its form and dimensions from a negative reference; this task is to be accomplished within five minutes.

![FIGURE 14. Task 4- Positive Model of Negative space](image)
Screen 14: This is the last screen within the Digital Charrette. With a color scheme similar to the first introduction screen, it thanks the test taker for their participation, and informs them that their scores would be used to supplement their application materials for admission to the graduate architectural program. Though not included within the development scope of the prototype, it is proposed that when developed further, this screen would display to the test taker their performance on each of the tests, and their total score.

The same screen layout is maintained for each of the tasks to increase readability of the Digital Charrette. The color scheme changes after the introduction screen and changes back to the introduction color scheme on reaching the final screen in order to clearly mark the beginning and end of the test taker’s experience within the Digital Charrette. The test taker’s performance on each of the task is e-mailed using a CGI mail script to the evaluator. It is proposed that a further development of the Digital Charrette would include tracking the positions of each of the blocks, in the event of the test taker failing to complete the task on time. This would help issue partial credit to the test taker if they were very close to completion of the task when it timed out. If the test taker completes the task within the allotted time, it is proposed that the exact time taken to complete the
task should also be tracked and sent to the evaluator. In the event of two or more applicants with the same scores competing for a placement in the graduate program, this tracked time would help the evaluator make a decision. This would also help understand the failings, if any of the design of each of the tasks, i.e. if many test takers are unsuccessful at the same point within the Digital Charrette.
CHAPTER IX

EVALUATION OF THE DIGITAL CHARRETTE

Chapter IX discusses the evaluation of the developed prototype of the Digital Charrette under the following titles:

A. Study Population
B. Testing Process
   i. Pre-task questionnaire
   ii. Task: Digital Charrette
   iii. Post-task questionnaire
C. Results
D. Discussion on how the evaluation results relate to the hypothesis
E. Limitations and Conclusion

A. Study population

The target population for evaluation of the Digital Charrette consisted of senior undergraduate architecture students, expected to be applicants to the graduate degree program in the near future. In view of the available time frame, the study population was restricted to students of Texas A&M University, taking Summer 2001 design studio.

This test was carried out with approval of the Institutional Review Board (IRB), Texas A&M University. In compliance with the IRB regulations, all the participants were enrolled on a voluntary basis and required to sign an ‘Informed Signed Document’ at the beginning of the evaluation process of the Digital Charrette.
B. Testing Process

This study design could be classified as the Quasi Experimental type (Kerlinger, 1973). The subjects were briefed regarding the objectives of the testing and the participants’ role in the same. In the evaluation that took about 45 minutes, the subjects first completed a pre-task questionnaire. They were then required to accomplish the tasks within the Digital Charrette, and at the end of it, submit their reactions to the Digital Charrette on a post-task questionnaire. The scores of the students on these exercises were compared to their previous design studio performance at the end of the Spring 2001 semester. The post-task questionnaire is to help understand user reactions to the Digital Charrette.

i. **Pre-task Questionnaire**

   The aim of the pre-task questionnaire was to determine the student profiles. The questions were grouped under their experience with computers, exposure to the Internet, familiarity with three-dimensional virtual environments, digital games or software, and prior contact with computer based testing.

ii. **Task: The Digital Charrette**

   As described in Chapter VIII, this consisted of a practice session after which the students were expected to complete four timed tasks.

iii. **Post-task Questionnaire**

   The post-task questionnaire helps in understanding user reactions to the Digital Charrette. The main concerns addressed by the questionnaire were feedback on the Concept, Interface and Design of the Digital Charrette. The questionnaire also had a detailed comments section where the test taker could explain in detail their impressions on the task and interface design, concept and perceived validity of the Digital Charrette in evaluating their spatial skills.
C. Results

i. **Pre-task Analysis:** Figures 16 to 24 below are representations of each of the issues addressed by the pre-task questionnaire and the statistics involved. The user profile is outlined in Section D below.

- **Use of computers in all settings:**

  ![Frequency of computer use](FIGURE 16. Frequency of computer use)

- **Experience with the Internet**

  ![Web Browser Preferences](FIGURE 17. Web Browser Preferences)
Experience with 3-D virtual environments, games and software

FIGURE 19. Familiarity with digital games
FIGURE 20. Experience with 3D modeling and other architectural software

FIGURE 21. Media Preferences in Architecture Design Studios
FIGURE 22. Experience with computer based testing

FIGURE 23. Medium preference for taking tests
ii. Task Results:

Six out of 13 test takers were able to solve Task 1-a, 1-b and Task 3; 2 out of 13 accomplished Task 1-c; 1 out of 13 finished Task 2; none of the participants were able to accomplish Task 4.
iii. **Post-task Analysis:**

Figures 26 to 29 below illustrate the user reactions to the Digital Charrette. These reactions are analyzed and related to their performance within the Digital Charrette in Section D of this chapter.

![Impressions on the Digital Charrette Interface](image1)

FIGURE 26. Impressions on the Digital Charrette Interface

![Reaction to Time-based exercises](image2)

FIGURE 27. Reaction to Time-based exercises
FIGURE 28. Subject Perception of the difficulty level on the Digital Charrette tasks

FIGURE 29. Perceived ability of the Digital Charrette to test spatial skills

- Detailed feedback:

  **Features of the Digital Charrette that subjects perceived as difficult or features that should be changed** (in the words of the subjects):
  - *VRML was inhibiting, it was difficult to navigate, and work within the virtual space, Most subjects felt that they would have performed better if they have more experience/ familiarity with*
VRML, and that manipulation of the VRML environment was what affected their performance.
- Timer should not run while I am reading the directions
- Wish there was an Undo feature, especially for task 2
- More light within the virtual worlds
- Initial tutorial should include a hands-on demonstration of how to move the blocks through a VRML world, More guided practice
- Since the blocks will not snap into place and since the mouse is very sensitive to movement, it was tough to manipulate the objects
- Either the time for doing the tasks needs to be increased or include a tutorial at the beginning of the testing
- The complexity of the problem seemed a little elementary for prospective graduate students

Favorable reactions of the subjects to the Digital Charrette (in the words of the subjects):
- Good tool, good concept: This was unanimous; each of the 13 subjects mentioned this in their detailed feedback
- Navigation was clear, Interface was good and clear, Colors were good
- Site is very well designed graphically, Frames were self-explainable, Nice presentation, Put together well
- Easy to understand, Clear exercises
- Exercises were well thought of, and it was easy to understand what to do
- Task Design was good
- Concept is extremely valid, the test would gain more reliability if minimum skill level of the subject with the VRML interface was assured beforehand
- Liked how on the last task, there was an example to remind you exactly what was supposed to happen to the blocks
- I think all 4 exercises address the concepts any architecture student should know

Suggestions of the subjects for further development of the Digital Charrette:
- A paper and pencil test should follow this test
- For each of the tasks, a sample task would be good
- Include the correct way of solving the task/ feedback
- Do the tasks need to be timed?
- I kept wanting to use the Autocad commands, since I’m so used to those...
- Can a wayfinding exercise be added?

D. Discussion based on how the evaluation results relate to the hypothesis
- The characteristics of the study population profile could be outlined as:
  - Comfortable with computers and the Internet
  - Familiar with 3D virtual environments, games and software (all subjects familiar with atleast one of the three)
  - Preference for paper-based media for presentations and testing

- The hypothesis that the performance of the subjects would be reflected in their design studio grades was proved true. A positive relation has been found as supported by figure 30 between the Digital Charrette scores of the subjects and the design studio grades. The design studio grade data was collected from the subjects on a voluntary basis for use in this analysis. Only 8 out of 13 test takers volunteered their design studio grades and only their scores have been used for the final analysis.
The reverse of the hypothesis was not found to be true. Subjects who had higher design studio grades did not necessarily perform well on the Digital Charrette tasks.

- The performance of the subjects on the Digital Charrette tasks showed no dependency on either experience with digital games, experience with VRML or experience with 3D modeling & other architectural software.

- The study population perceived the Digital Charrette as a good evaluator of their spatial skills. This result is important because the study population was aware of their performance on the Digital Charrette; the maximum score on the Digital Charrette in this particular evaluation scenario was 3 out of a maximum possible 6. The average score of most of the test takers was approximately 2. However, this did not cause a negative bias amongst the study population during their evaluation of the Digital Charrette, and they rated it positively. The study
population seemed confident of being able to perform better if they were more experienced with the VRML environment.

E. Limitations and Conclusion

- The study population is limited and biased, and random sampling is not included. Hence, the external validity of the study design is not applicable, since the results cannot be generalized. The results may therefore be considered as suggestive rather than conclusive. Since the study population consists of senior undergraduate students, for the same school, it is not possible to use re-testing to establish the reliability of the methods used to measure the variables.

- The length of the practice session with the VRML environment was left to the subject’s discretion. Because of this, most of the test takers skipped the session and moved to the actual task. This contributed to the failure of some of the test takers in completing their timed tasks, as they were struggling with VRML player controls during the task time allotted.

- Using VRML environment to conduct these three-dimensional tests imposed a bias, and thus the test taker was unable to perform the tasks without being inhibited by the medium. However, during a real-life scenario, it is expected that the test takers would be informed earlier that their admission process is to be supplemented by the Digital Charrette. This would encourage the test takers to gain experience with the virtual environment and, they would take the test only when they are confident of navigation and object manipulation within VRML worlds.

- Currently, the score reporting is not consolidated, and the evaluator is sent the scores of each task of each test taker separately.
- The Digital Charrette is not designed to be a stand-alone applicant evaluator.

- This study has other limitations also since factors that may have contributed towards the scores of the students on the Digital Charrette have not been included in the scope of the proposed research:
  - Student motivation/ inhibition
  - Time available to complete the exercises/games
  - Previous educational/ computer experience of the student
  - Compatibility of the proposed model with current admission procedures

**Conclusion:** Since there is a positive relation established between the Digital Charrette scores and the subject’s design studio grades, it would be worthwhile to conduct further research in this area and add sophistication to the VRML environment and particularly, the score reporting. The study population unanimously agreed that the concept of the Digital Charrette was an important one, and would be very useful if completely developed. This study thus contributes towards testing applicants to graduate architectural programs in a visual three-dimensional language, a metaphor for this would be ‘computerized GRE for architecture students’.
CHAPTER X

FUTURE RESEARCH

This chapter enumerates different possibilities for future research and development of the Digital Charrette, a web based testing tool for supplementing the admission procedure to graduate architectural programs.

After analysis of testing results for the Digital Charrette, further research is recommended in the following areas:

- Additional complexity may be incorporated into design of the spatial tasks within the Digital Charrette. Since this development was an initial prototype and was designed for a short testing time (total task time: 16 minutes), there was limited possibility of testing the subjects on architectural-contextual spatial exercises.

- Further testing is recommended using random sampling of senior undergraduate students and also, first year graduate architecture students to establish both reliability and validity of the Digital Charrette. This would also help putting forth concrete statements on the utility of the Digital Charrette in the admission procedure; the conclusions of the current study are only suggestive due to the small study group.

- VRML does not directly allow object-to-object collision detection. Due to this, when the users manipulate objects within the Digital Charrette, the blocks move through each other defying their perceived solid three dimensional character, and this may be confusing to the test takers.

- Artificial intelligence may be incorporated into this tool so that it is able to both record and evaluate the students’ efforts. Also if all the test taker information is
channeled into a database, it would be useful to establish patterns between student profiles, their scores on the other admission criteria and their scores on the Digital Charrette. This information would also be useful in identifying possible improvements to the Digital Charrette.

- A completely developed model of the Digital Charrette could be administered either over the Internet, or in world-wide testing centers similar to GRE and GMAT. This testing model may also be extended to supplement undergraduate admission procedure.

- It is also recommended that further work be done on improving the interface and interaction, based on user feedback to make it more intuitive.

- The total score on the Digital Charrette should be reported to both the test taker and the evaluator. This requires information to be sent over a network, and hence VRML would have to be integrated with Java to achieve this. The test taker could also have the option of canceling their scores on the current test, if they are dissatisfied with their performance on their tasks.
CHAPTER XI

SUMMARY

This research explores the possibility of incorporating Web-based testing within virtual environments, to supplement the admission procedure to graduate architectural schools. The Digital Charrette endeavors to overcome the limitations of the other admission criteria by supplementing the current established admission procedures, and thus, to allow a fair evaluation of the applicants.

The NAAB sets standards for both students and the graduate architectural program curriculum. Since this research focuses on professional graduate architectural degree programs, the student scores on the architectural design studio would determine their success in the program. This study began with a hypothesis that a positive correlation would be found between an applicant’s scores within the Digital Charrette and their design studio performance. For testing purposes, the test taker’s earlier design studio grades were used for comparison and analysis. The evaluation involved 13 undergraduate senior participants of Texas A&M University, enrolled on a voluntary basis. Their profiles were identified using a pre-task questionnaire, after which they were required to complete the tasks within the Digital Charrette. Finally, their reactions and suggestions were collected using a post-task questionnaire. The hypothesis was proved true at the end of the evaluation process.

Analysis of the results showed that the test takers thought the Digital Charrette was a good evaluator of their spatial ability. The study population showed a preference for paper-based media in the pre-task analysis. A huge percentage of the study population found the Digital Charrette ‘fun to do’ and ‘challenging’ and there was also a considerable percentage who found the tasks ‘inhibiting’. The major drawback of this study was that the VRML environment was unable to render itself for testing purposes in a way that the medium would not hinder the test takers’ performance. This may also be
considered a cause for a relatively smaller percentage of successful test takers. The study population however unanimously considered the concept of the Digital Charrette, i.e. testing in virtual environments significant to evaluation of architecture students.

In addition to supplementing the admission procedure to graduate architectural programs, this study also contributes to customized web-based testing systems, using digital media for testing spatial ability and using virtual environments for testing architecture students.

This research is an attempt to enable evaluation of worldwide applicants to graduate architecture degree programs in the United States on a standardized common platform, and at the same time help the graduate architectural committee by giving them a supplementary tool to evaluate the applicants.
REFERENCES


APPENDIX A

The following is a list of reference material used during the development of the tasks within the Digital Charrette. Some of the testing blocks used may closely resemble three-dimensional forms seen in the references listed below:

- Interactive Tutorial on Spatial Intelligence:
  <http://www.ul.ie/~mearsa/9519211/newpage2.htm>

- Spatial IQ tests: <http://www.queendom.com/tests/eq/spatial_iq.html>

- Spatial Test Battery, Center for Talented Youth, John Hopkins University:
  <http://www.jhu.edu/gifted/stb/>
APPENDIX B

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April 9, 2001

MEMORANDUM

TO: Kameshwari Viswanadha
   Department of Architecture


The above referenced protocol has been:

   X Approved April 9, 2001 – April 8, 2002
   ___ Conditionally Approved (see remarks below)
   ___ Disapproved (see remarks below)
   ___ Tabled (see remarks below)

by the Institutional Review Board - Human Subjects in Research.

The study has been approved for one year. Your protocol must be re-approved each year. If you desire to make any changes in your research protocol, the changes must be approved by the IRB before they are initiated. Any adverse reactions or events must be reported immediately to the Board.

E. Murl Bailey, Chair
Institutional Review Board - Human Subjects in Research
VITA

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Education : M.S. Architecture, Texas A&M University, 2001
            B.Arch, University of Mumbai, India, 1997

Work Experience

- Oct 2000- Aug 2001 - Graduate Assistant, Learning Online Team, Texas A&M University

- Aug 1999- Sep 2000 - Graduate Assistant, Cognition & Instructional Technologies Labs, Texas A&M University

Others

- Elected Member of the Honor Society of Phi Kappa Phi, Texas A&M Chapter

- Co-ordinator for SpicMacay, Texas A&M University, TAMU (August 2000- August 2001)

- Registered with the Council of Architecture, India

- Selected as a member of a part of 4-member team during undergraduate degree to visit London and Paris for the study of Contemporary Architecture