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An exploratory study: Reading and spatial visualization ability as predictors of success for technical drawing

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AN EXPLORATORY STUDY:

READING AND SPATIAL VISUALIZATION ABILITY

AS PREDICTORS OF SUCCESS FOR TECHNICAL DRAWING

An Abstract of a Dissertation

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Industrial Technology

Approved:

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ABSTRACT

If one were to open a technical drawing book, the reader could make the observation that the book was "written" and "read" in two languages--the English language and the universal graphic language. The technical drawing is presented in the context of these two languages: written statements accompanied by their graphical translations. The two seemingly symbiotic languages are synergistically integrated in technical drawing.

The problem of this exploratory study was to determine the strength of the bivariate correlational relationships between students' assessed spatial visualization ability and their reading ability to their assessed achievement in technical drawing. Further, the problem of the study was to determine the strength of the multivariate correlational relationship among these same variables.

The purpose of the study was to provide technical drawing instructors, career counselors, and advisors with an advising and placement tool which could be used to assess students' abilities. This assessment could minimize failure and the loss of time occasioned by false starts in inappropriate technical curricula for the individual student.

Three research questions were established for this study based upon the lack of conclusive research findings in the literature which would have led to the development of directional hypotheses. The data collected from the cluster sample of 38 students were examined at the .05 level of significance.

Based upon the analyses of data, it was concluded that the correlation between the students' assessed spatial visualization ability and their assessed achievement in technical drawing was not statistically significant. Further, it was concluded that the correlation between the students' assessed reading ability and their assessed achievement in technical drawing was statistically significant. Lastly, it was concluded that the multiple correlation among the students' assessed spatial visualization ability, reading ability, and their assessed achievement in technical drawing was not statistically significant.

Given the outcomes of the study, recommendations for further study were warranted and may be utilized to further define the relationship between students' spatial visualization ability, reading ability, and their achievement in technical drawing. It was recommended that this exploratory study be replicated. In addition, other recommendations for further study were also made.

DEDICATED TO

MY WIFE

VICKI LEA

ACKNOWLEDGEMENTS

In taking this opportunity to reflect back over several year's work, I want to take a moment to thank those who have given of their time and effort to help make this dissertation something of which I can be proud. With that thought in mind, I express my deepest appreciation to the following people.

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TABLE OF CONTENTS

Page

CHAPTER Page

LIST OF TABLES

TABLE | Page

TABLE | Page

CHAPTER 1

INTRODUCTION TO THE STUDY

Prologue

Since 1991, this author has conducted an exhaustive and comprehensive examination of traditional and contemporary technical drawing books, while teaching technical drawing courses. This has taken the author through a review of several hundred books published in the United States during the period from 1849 through 1997 and as a result of this review, several important observations have been made.

If one were to open a technical drawing book, the reader could make the same observations. Every one of the books examined was found to be "written" and "read" in two languages--the English language and the universal graphic language. Technical drawing problems are always presented in two languages: a written statement accompanied by its graphical translation, with an emphasis placed on the graphical presentation with the written material condensed to its essentials (Higbee, 1938).

Upon further examination these two languages are shown to be distinctly unique and yet startlingly similar. The reader is asked to recognize that although this author will use the term "English language" throughout this study, it is understood that the same observations would be made for any language when it is combined with the universal graphic language in a technical drawing textbook.

The first and most easily identifiable language found in these books are the individual letters, words, sentences, and paragraphs on the page. It is the English language. It is both written and read by every literate person in the United States. However, the readers and writers of other languages must laboriously struggle to interpret the English text, since meaning is found not in the words alone, but in the visual images they bring to an individual's mind in a given context. "Meaning is . . . provided by the listener or reader" (Smith, 1994, p. 25).

The second language is also written and read, but it is unique in that it is "universal and timeless in character" (Giesecke et al., 1997, p. 2). This second language provides the foundation and framework of technical drawing. It has been identified and characterized by numerous authors, including Giesecke et al. (1997), for a century or more as the one "universal graphic language".

The uniqueness of the universal graphic language is that it has been adopted and adapted around the world, with technical personnel most often recognized as its writers and readers. Unlike the English language, the graphic language is universal in that it is interpreted in the same way by writers and readers around the globe. It does not share the difficulties of colloquialisms like the English language.

The successful "reader" of the technical drawing text must possess two distinct--but not entirely discrete--skills or abilities in order to understand and utilize the content of the text. First, he or she must possess an ability to read and understand the written words--the English language. Second, he or she must possess an ability to read and understand the graphic illustrations--the universal graphic language. However, only when the two languages are synergistically combined, is one able to fully understand and comprehend the language of technical drawing in its entirety.

In order to become fully literate in technical drawing, the reader must combine functional and technological literacy. The basic ability to read and write is functional literacy. Barr, Kamil, Mosenthal, and Pearson (1991) suggested that functional literacy was the area of overlap between print literacy and functional tasks. Therefore, functional literacy is based upon the reader's ability to respond competently to real-world reading tasks.

The ability to read and write the universal graphic language is a primary element of technological literacy. French and Vierck (1978) stated, "technical drawing should be understood by all connected with, or interested in, technical industry. . . . even one who may never make drawings must be able to read and understand them or be professionally illiterate" (p. 4). The universal graphic language is interpreted--and understood--through the use of an individual's spatial visualization ability. Spatial visualization or the ability to think in three dimensions, is to the universal graphic language what reading comprehension is to the English language.

Students demonstrate their spatial visualization ability by comprehending forms in space and understanding relationships of plane and solid figures or objects. This ability to visualize objects in two or three dimensions or to think of them visually as geometric forms is called spatial visualization. In practice and application, this means that the student forms a mental picture of the three-dimensional shape. Further, it means the technical drawing student may need to demonstrate an ability to synthesize a mental image even before an object exists. This is the essence of technical design drafting.

The synergistic application of these reading and writing abilities is perceived by this author to be a factor in predicting a student's success or optimal level of competence in the discipline of technical drawing. In technical drawing, the student must be able to read, write, and interpret both languages. As a result of his or her "reading" ability, the student responds or takes an action based upon that reading.

This response or action demonstrates the reader's level of understanding or comprehension. In the case of technical drawing, this understanding must be directly linked to the graphical language which accompanies it. The immediate and practical application of the English language, in concert with the universal graphic language, is a predictor of success in both the technical drawing classroom and subsequently, in the workplace. In technical drawing, the languages operate hand-in-hand.

Although history has shown that the universal graphic language preceded the spoken and written language, the two are inextricably linked in the study and mastery of technical drawing. Like the proverbial chicken and its egg, regardless of which came first, both languages must be utilized simultaneously. The languages are distinctly symbiotic and yet they are completely and uniquely synergistic in their practical application within the discipline of technical drawing.

The universal graphic language--technical drawing--requires the complete combination of these abilities--reading and spatial visualization. They are skills which lead to success in many career areas, including technical drawing. The significance of technical drawing is illustrated in the following statement by P.J. Booker (1979),

> Drawings are like windows through which we see things. The draughtsman, who is a maker of these windows, appreciates the effort put into them much more so than others, who only see through drawings, as it were, to the things themselves depicted and so take drawing for granted.
>
> In its narrowest sense engineering drawing is a language used for communication. However, languages in general are not only useful for communication; they play an inherent part in our very thinking, for we tend to think in terms of the languages we know. Drawing is of this nature, and he who can draw can think of, and deal with, many things and problems which another man cannot. (p. xv)

Technical drawing is the "picture window" through which the technological world may be viewed and understood. Visual literacy provides a linking pin to virtually all other areas of literacy, including technological literacy. Hubbard (1988) said, "the study of literacy is all too often a matter of spinning words about words, without looking back to the images that precede words" (p. 4). Technical drawings are the images that precede the written words and spatial visualization is the ability to read these images clearly.

The students' ability to read, write, and speak words and their spatial visualization ability are combined synergistically in the learning and application of the universal graphic language of technical drawing. This study was based upon the author's initial observations and subsequent hypothesis that these previously unexplored relationships are both significant and worthy of research.

Statement of the Problem

The problem addressed by this exploratory study was to determine the strength of the bivariate correlational relationship between introductory technical drawing students' assessed spatial visualization ability and their assessed reading ability to their assessed technical drawing achievement. Further, the problem of the study was to determine the cumulative strength of the multivariate correlational relationship among the students' assessed spatial visualizationability, reading ability, and their assessed technical drawing achievement, resulting in a data-based multiple regression prediction equation.

Statement of Purpose

The purpose of this study was to provide a career and post-secondary program of study advising and placement tool to community college technical drawing instructors, career counselors and advisors. The knowledge gained from this study can be used as a measurable means of providing appropriate and timely advising to post-secondary technical drawing students.

The results of this research can provide useful information for the academic advising and placement of students in many technical programs of study. In that way, the students' chance of failure could be minimized and the loss of time occasioned by false starts in inappropriate technical curricula could be prevented. This would help both the students and the college in accomplishing their career goal and educational mission respectively, while assisting the instructor in improving contemporary educational practice.

Significance of the Study

The individual significance of spatial visualization ability, reading ability, and technical drawing ability will be delineated in the following paragraphs with an emphasis on the inextricable thread which binds them one to the other. It is their combined synergistic significance in an increasingly complex and technological society that was the catalyst which provided direction for studying these previously unexplored relationships.

Spatial Visualization Ability

Like its reading counterpart, spatial visualization ability has been identified by authorities as being vital to success in many, if not all, career areas (Baartsman & Sorby, 1996). Spatial visualization skills are characterized by an ability to think three-dimensionally, forming clear mental images of geometric forms. "Visualization is simply a means of getting a three-dimensional idea" (Giachino & Beukema, 1978, p. 407).

"All authorities agree that the ability to think in three dimensions is one of the most important requisites of the successful scientist and engineer" (Giesecke et al. 1991, p. 9). However, it is not just the scientist and engineer who benefit from this ability or skill. Many if not all technical personnel must have outstanding abilities in spatial visualization. Like reading, "the ability to visualize is . . . essential" (Gibby, 1965, p. 79-80).

"There is . . . evidence that an active what-if imagination is a key ingredient in the visualization process" (Goetsch, Nelson, & Chalk, 1994, p. 158). A student's spatial visualization ability is simply the demonstrated use of that what-if or constructive imagination. It is also known that "the ability to visualize is possessed in an outstanding degree by persons of extraordinary creative ability" (Giesecke et al., 1967, p. 8).

In understanding technologies, the student must be able to visualize or think in three-dimensions. The written words can complement and supplement, but rarely, if ever, supplant the ability to think in three-dimensions as learned through the application of the universal graphic language. However, it is understood that a technical drawing can replace the verbal language when it fails to communicate effectively (Glidden, 1964)

Reading Ability

It is documented that "comprehension is the purpose of reading" (Orasanu, 1986, p. xi). And that "understanding is the basis not the consequence of reading" (Smith, 1994, p. 3). If you don't learn to use language so that you control it, then it is going to control you. Purposeful reading allows an individual to control language.

Words are the tools of thinking, i.e., we think in terms of language. Reading then becomes a process of interaction between the reader and the text being read. As a result of this interaction, reading becomes thinking. The words on the page become the tools with which one builds thoughts. Without the ability to read and to comprehend what has been read, one cannot use these building blocks of thought. The individual demonstrates an ability to process language in order to fulfill functions that have short- and long-term consequences for the individual and for society (Richardson, Martens, & Fisk, 1981, p. 7).

Language is perhaps the most important single characteristic that distinguishes human beings from other species. The centrality of language in human life is not contested. In its amazing complexity, flexibility, and range of expression, language is as fascinating as it is opaque. Language is the means of human communication, when it is spoken or written or read. It is also the faculty of speech and a style or faculty of expression. It is the controlled use of words. Further, the written word makes permanent our perishable thoughts.

Hillerich (1990) stated, "Reading is a skill, like many others, for which one must have a certain degree of aptitude" (p. 48). "Most specialists agree that an eighth-grade reading ability is the minimum level of functional literacy" (Harmon, 1986, p. 4). Later, Harmon writes a caveat stating that in order to master the details of contemporary American life, an eighth-grade reading level is not sufficient.

Reading is also a mental visualization process. The visual symbols, i.e., the letters and words, which are seen on the page are the means by which the mind interprets what is read (Hancock, 1987). Reynolds (1992) builds on this notion when he writes, "The term reading, in its broadest sense, includes the processing of information from sources other than words. Good readers should be able to deal with pictures, symbols, tables, charts, and graphs that convey information" (p. 241). When reading, the reader must be able to comprehend and understand a number of visual images.

Technical Drawing Ability

Walter Smith (1875) stated, "the power to draw depends upon two things, which are essential to successful drawing; they are (a) the faculty of understanding and (b) skill of the hand" (p. 7). This faculty of understanding is the same kind of understanding a reader of words must demonstrate. Smith (1875) went on to say that technical drawing is the way to "talk through the eye to the understanding" (p. 9).

Technical drawing as a "subject is essential . . . and should be understood by all connected with, or interested in, technical industry. . . . even one who may never make drawings must be able to read and understand them or be professionally illiterate" (French & Vierck, 1978, p. 4). Earlier, French (1941) had written, "Everyone connected with technical industry must be able to read a drawing without hesitation. Not to have that ability would be an admission of technical illiteracy" (p. 114). French (1911) summarized the significance of technical drawing when he wrote, "as the foundation . . . drawing becomes, with perhaps the exception of mathematics, the most important single branch of study" (p. 2).

Like reading, the universal graphic language provides powerful visual images, as suggested by the proverb, "A picture is worth a thousand words" (Davis & Newstrom, 1989, p. 70). "Actually, a picture is worth much more" when you consider that "the speed of graphic comprehension can approach a rate 50,000 times that of reading" (Voisinet, 1987, p. 1).

Technical drawing has played an important role in the past and continues to play an important role in the present. However, its most important role will be played out in the future. The optimal development of new and emerging technologies will be derived from technical drawings. The technical drawing will result from a technician's ability to read, write, understand, and take action in conjunction with his or her ability to spatially visualize objects and geometric relationships. It is widely accepted that

> From the dawn of history the development of technical knowledge has been accompanied, and to a large extent made possible, by a corresponding graphic

> language. Today the intimate connection between engineering and science and the universal graphic language is more vital than ever before. (Giesecke et al., 1991, p. 8)

Statement of Research Questions

Research questions were established for this study based upon the lack of conclusive research findings in the literature which would lead to directional hypotheses. The following research questions were made in regard to this study:

1. What is the strength of the bivariate correlative relationship, expressed as a Pearson Product-Moment Coefficient of Correlation (r), between introductory technical drawing students' assessed spatial visualization ability, as measured and evidenced by The Psychological Corporation Revised Minnesota Paper Form Board Test (RMPFBT) Series AA and their assessed achievement in technical drawing, as measured and evidenced by the National Occupational Competency Testing Institute (NOCTI) Job Ready/Student General Drafting and Design written assessment?

2. What is the strength of the bivariate correlative relationship, expressed as a Pearson Product-Moment Coefficient of Correlation (r), between introductory technical drawing students' assessed reading ability, as measured and evidenced by the CTB/McGraw-Hill Tests of Adult Basic Education (TABE) Form 7, Level A Complete Battery Reading Subtest and their assessed achievement in technical drawing, as measured and evidenced by the National Occupational Competency Testing Institute (NOCTI) Job Ready/Student General Drafting and Design written assessment?

3. What is the strength of the multivariate correlative relationship, expressed as a Multiple Correlation Coefficient (R), among introductory technical drawing students' assessed spatial visualization ability, as measured and evidenced by The Psychological Corporation Revised Minnesota Paper Form Board Test (RMPFBT) Series AA, their assessed reading ability, as measured and evidenced by the CTB/McGraw-Hill Tests of Adult Basic Education (TABE) Form 7, Level A Complete Battery Reading Subtest, and their assessed achievement in technical drawing, as measured and evidenced by the National Occupational Competency Testing Institute (NOCTI) Job Ready/Student General Drafting and Design written assessment?

Assumption

A single assumption was made in regard to this study. It was assumed that all of the subjects of this study, because they were taking the same technical drafting course during the same academic semester and from the same technical drafting instructor, were receiving the same instruction as that received by previous students, i.e., the study was not intended to measure any instructional outcomes.

Delimitation

Geographically, this study was delimited to Iowa Service Delivery Area (SDA) 7. SDA 7 is one of 15 education subdivisions in the state of Iowa. It includes parts of 10 northcentral and northeast Iowa counties which are: Benton, Blackhawk, Bremer, Buchanan, Butler, Chickasaw, Fayette, Floyd, Grundy, and Tama. SDA 7 is served by

Hawkeye Community College, an accredited, two year, open access, public comprehensive community college, located in Waterloo, Iowa.

Definition of Common Terms

Certain terms that were used, although not unique to this study, have been defined to clarify their use in order that readers have a common basis for understanding their use within the context of this research. The following terms are defined:

Graphic--"vividly descriptive; conveying all . . . details" (Abate, 1996, p. 640). Also, "the art or science of drawing a representation of an object on a two-dimensional surface according to mathematical rules of projection" (Mish, 1987, p. 533).

Language--"a systematic means of communicating ideas or feelings by the use of conventionalized signs, sounds, gestures, or marks having understood meanings and understood by a considerable community" (Mish, 1987, p. 672-673). Further, it is "any method of expression" (Abate, 1996, p. 840).

Learning--"an action, whereby the learner is acquiring knowledge or skills through study and systematic instruction" (Abate, 1996, p. 852).

Read--reproduce mentally or vocally or interpret mentally or understand and interpret the written or printed words (of a book, author, etc.) by following the symbols with the eyes or fingers" (Abate, 1996, p. 1247-1248).

Reading--the act of reading; an interpretation or view taken or an interpretation made of (a book, an author, etc.) (Abate, 1996, p. 1248).

Spatial Visualization--"the ability to visualize or think in three dimensions" (Giesecke et al., 1997, p. 195). It is also "the ability to mentally manipulate, rotate, twist, or invert pictorially presented mental stimuli" (McGee, 1979, p. 893).

Teaching--"an action, whereby systematic instruction or information about a subject or skill is provided to another person" (Abate, 1996, p. 1567-1568).

Technical drawing--"a broad term that adequately suggests the scope of the graphic language. It is rightly applied to any drawing used to express technical ideas" (Giesecke et al., 1997, p. 7).

Universal--"including or covering all or a whole collectively or distributively without limit or exception" (Mish, 1987, p. 1291).

Universal graphic language--a systematic means of communicating technical ideas by drawing a representation of a three-dimensional object on a two-dimensional surface according to mathematical rules of projection using a conventionalized alphabet of lines and other symbols having globally understood meanings without limit or exception.

Summary

Business and industry will continue to experience radical and rapid technological change requiring new skills and new knowledge for both present and future employees. In addition to the new skills and knowledge that will be required, there will continue to be a need for traditional skills and knowledge related to reading ability, spatial visualization ability, and technical drawing ability. When these abilities are developed and applied in combination to the optimal advantage of the student, a powerful synergistic relationship is established between these three seemingly symbiotic elements. The student's optimal development and the interaction between his or her head, hands, and eyes while reading, visualizing, and doing technical drawings make these things the critical elements in a student's short- and long-term success.

The individual significance of the elements of the study are obvious. However, it is their combined significance which provides the foundation for and the opportunity to both construct and conduct this significant and scholarly study. This author contends that a previously unexplored relationship exists among the students' reading ability and their spatial visualization ability relative to their achievement in technical drawing. This study provided the opportunity to determine the strength of the relationship between the independent or predictor variables--the students' reading ability and spatial visualization ability--to the dependent or criterion variable--the students' competence or success in technical drawing.

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

Introduction

In the review of related literature, a wide variety of materials have been examined. The review of literature has been delineated under four major headings. Those headings are: (a) Technical Drawing: Predicting Its Success, (b) Spatial Visualization Ability as a Predictor of Success, (c) Reading Ability as a Predictor of Success, and (d) Reading Ability and Spatial Visualization Ability as Predictors of Success for Technical Drawing.

In regard to this study, the author has observed that the context within which any body of knowledge is viewed and regarded alters the interpretation and contribution of that knowledge. What follows is the author's review and view of the related literature. The author has refrained from replacing the old with the new just for the sake of updating. He has elected to stand on the shoulders of those who have gone before to raise his own flag. Many of the less than contemporary citations found within this study have stood the test of time. The author has chosen not to support any idea that the latest research is always the most significant or the most reliable. Rather, the author maintains that real learning occurs when new things are presented in terms of the old, especially when those things have stood the test of time. The following review is presented to the reader in the embrace of that tenet.

Technical Drawing: Predicting Its Success

In consideration of the importance of technical drawing as the universal and timeless graphic language, the material which follows is presented as an overview of the research which has been conducted in an attempt to predict student success in technical drawing and closely related areas of study. It is noted that few studies were found which dealt with predicting success in technical drawing at the community college, while there are numerous studies relative to predicting success in college and university engineering drawing programs.

In 1959, Waggoner constructed and prepared three types of items in order to evaluate three-dimensional spatial visualization test items as predictors of success in engineering drawing. Waggoner developed a test of spatial visualization which included 20 block building items, 20 object visualization items, and 30 light and shadows items. Analyses were based on the test being administered to 361 first semester students and 70 prospective first semester students. He found only a moderate relationship existed between final course grades and total spatial test performance. Waggoner also found that a moderate to substantial relationship existed between the mid-semester ratings and the total test scores. He also found that his test had a corrected reliability coefficient of .90, however, he recommended that the instrument needed to be revised.

Horine (1961) conducted research on the relationship between high school drafting experience and achievement in engineering drawing at the college level. He found that the difference in grades between students with and without high school experiences were statistically significant. Students with high school drafting experience also scored higher on visualization tests than those without that experience. Horine concluded that students with experience earn higher grades in college level drafting courses than those without experience.

Dyke (1962) examined the relationship of student performance in mechanical drawing courses with success in engineering drawing courses based on the grade received in mechanical drawing, as well as other factors, including semesters of mechanical drawing experience in high school. The data relevant to the sample of 496 first semester students was analyzed using the Pearson product-moment correlation. Dyke found that the Pre-Engineering Abilities Test was the most valid predictor of probable success in engineering drawing showing a positive relationship to grades.

Ryan (1964), as had others, studied student performance in first year technical drawing as related to certain high school courses and ACT test scores. He reported that his research supported previous studies in that there was no correlation between the amount of high school mechanical drawing and mathematics and performance in college technical drawing. A major recommendation of Ryan's was that students that scored significantly higher in technical drawing than their sub-group counterparts should be examined in more detail.

Blum (1965) conducted research in the development of a standardized achievement test for the placement of students in general drafting courses. The test content was built around data derived from a nation-wide survey of college drafting instructors. The returns represented 119 institutions in 37 states. Blum constructed ten sub-tests covering the ten common units of instruction and had an expert panel evaluate the instruments. A sample of 164 students were administered the tests. In his findings, Blum reported that the tests showed significant correlation with semester course grades. Reliability coefficients of .84 to .95 were found as a result of 3,657 observations from 71 institutions in 31 states.

Lemons (1965), a colleague of Blum, conducted research into the relationships between mechanical drawing experience, knowledge of drawing fundamentals, and certain academic measures of ability, including mathematics and English aptitudes, for the purpose of assigning students into accelerated engineering drawing classes. He concluded that previous experience provided sufficient knowledge for placement into accelerated classes. However, paradoxically he found that this experience did not preclude the knowledge of drawing fundamentals being removed from the content of the accelerated courses.

Hilton (1965) studied the relationship between selected variables and academic achievement for drafting and design technology students. His primary purpose was to attempt to identify those students that had the best opportunity for success within the program of study. He also looked at retention of those students applying for and accepted for admission. Using multiple regression, with a sample size of 396 first year students, Hilton attempted to determine the most pertinent predictor variables when the criterion is academic achievement as measured by the student's grade point average.

Although 32 predictor variables were defined with the criterion, it was determined that 27 of these variables could be eliminated without a significant reduction in the multiple correlation coefficient. It was noted that two of the five remaining variables were arithmetic and algebra test scores from the Pennsylvania State University Academic Aptitude Examination, while father's income and occupation represented two of the remaining three predictor variable positions. Hilton concluded that his findings needed to be studied in more depth before his prediction equations could be used effectively.

Boone (1966) examined the relationship between selected high school subjects and achievement by first year engineering students. He found that a significant product-moment correlation existed between high school grade average and Scholastic Aptitude Test scores relative to academic achievement for the 411 students studied. A number of variables were not significantly correlated to achievement including high school rank.

Gallessich (1967) also examined factors associated with academic success of first year engineering students. The purpose of her research was to improve prediction of success, as measured by factors including grade point average, within the engineering curriculum. Ultimately, Gallessich concluded that her results pointed to the complexity of predictive models for academic achievement and that overall, scholastic aptitude translates into success in college.

Boone and Gallessich both recommended that further research should address itself to the refinement of any criteria of success. Elkins (1972) conducted a similar investigation and ended with like findings and recommendations. Predicting academic success for engineering technology students was also the focus of a 1973 study by Guard. Findings in regard to the selected factors were statistically significant, but of little value for predictive utilization because only 12% of the variance in student success was accounted for cumulatively by the predictors.

Armbrust (1969) investigated the role of selected non-verbal intelligence factors relative to success in beginning drafting. An instructor's term or course grade was utilized as the criterion for success. The Differential Aptitude Test Battery and the Otis Quick-Scoring Mental Ability Test were administered to a sample of 118 students. Additional data were collected from student cumulative records. An index of non-verbal intelligence was derived from the data using a multiple regression procedure and a prediction equation was developed to predict the drafting course grade. Armbrust found that drafting success was seldom associated with only a single trait. However, he concluded that the non-verbal intelligence concept was valid.

Krantz (1970) predicted success in first year drafting for college students through the use of geometric forms. The geometric forms were constructed by the researcher and were three-, four-, and five-unit three-dimensional blocks which when correctly assembled created a large rectangle. The sample of 112 students were asked to answer multiple choice questions relative to the forms and draw orthographic views of self-assembled three-dimensional blocks. The criterion of success was mid-term and final grades. The conclusions relative to the predictive nature of the forms was inconclusive.

Mireles (1977) conducted an investigation of selected factors associated with industrial training programs correlated to the success of engineering draftspersons. Mireles administered the Differential Aptitude Test Battery and the Motivational Analysis Test to 65 drafting trainees. Multiple regression analysis was used to analyze test data. In his findings, it was reported that no significant correlation existed between contact hours of instruction and success. However, with the exception of the Language Usage Test, all tests from the Differential Aptitude Test Battery were significantly correlated to success.

Moore (1982) measured field independence using the Group Embedded Figures Test and the Portable Rod-and-Frame Test in predicting success as measured by final grades in engineering graphics courses. The tests were administered to 80 students and the Pearson product-moment correlation coefficient was used to analyze the relationships between variables. Moore reported that both tests had validity as predictors of success in engineering graphics.

Kelley (1985) also used the Group Embedded Figures Test and the Hidden Figures Test as predictors of success in engineering graphics. Test scores correlated significantly with success as measured by the final grades of the 166 students who had taken the tests. Kelley reported that both tests have validity as predictors of success in engineering graphics.

Spatial Visualization Ability as a Predictor of Success

It has been found that engineering students without 3-D visualization skills are bound to fail and that spatial visualization skills have been identified as being essential for success in over 86 career areas (Baartsman & Sorby, 1996). It is not just engineering students who may fail as a result of demonstrating low level spatial visualization skills.

In consideration of the many technical career areas needing people who must demonstrate spatial visualization skills, a number of research studies have examined spatial skills as they relate to success in a variety of discipline areas. Several of these studies are highlighted below. Although a number of studies reviewed earlier in this chapter contained a spatial visualization component or variable, they will not be reiterated in this section.

Handler (1976) conducted an exploratory study of the spatial visualization abilities and problem solving processes of mathematics students. She emphasized the fact that spatial visualization is gradually being recognized as an important factor in scholastic and occupational success, and as a pervasive, fundamental mode of thinking. It is of interest to note that Handler's experimental results indicated that reading may interfere with spatial visualization, and that oral presentations may be superior to written presentations for spatial problems. Handler's sample consisted of 25 students who were asked to solve a set of 10 experimental geometric problems, in addition to being given the Differential Aptitude Tests to measure spatial visualization ability.

In 1978, Dorsey examined the relationship between visualization skills and the learning of science concepts. The primary purposes of this research was to determine if there were significant differences in the visualization ability of students by grade level and whether there was a significant correlation between a student's visualization skill and his or her grade point average in science courses. Using the Pearson product-moment correlation coefficient, Dorsey found that there were significant correlations between grade point averages and visualization skills. He concluded that visualization skills are helpful in learning science and that students visualization skills improved when they encountered courses where such skills are used. In addition, he concluded that many students could be helped in their understanding of scientific principles if they were provided with appropriate visualization experiences before taking certain courses.

Hill (1978) conducted a study of the relationship between visualization and performance in solving problems in science. Using a sample of 88 students, Hill concluded that a typology for visualization was needed to bring order to the various ways in which the process was described in the literature. He found no positive correlation between student scores on a test of spatial visualization and the battery of problem-solving tasks.

Konsin (1980) studied spatial visualization and mathematical problem solving ability. She noted that two variables consistently identified in factor analytic research studies relative to mathematical problem solving are verbal and spatial skills. With a sample of 242 students, Konsin conducted an exploratory study finding that students with high spatial skills were more successful in problem solving than those with low spatial skills. She concluded that although spatial visualization skill influences mathematical problem solving, other variables must be considered in any future research. Konsin recommended that a combination of factors be examined rather than using spatial visualization alone.

Hsu (1983) constructed a pictorial or graphic physics test and analyzed its relationship to science aptitude. A stem picture representing the question and three or four choice pictures were provided as multiple choice responses. Using a sample of 540 students, Hsu found that the practical advantages, reliability, and validity of the pictorial physics test indicated that it provided a potentially unique and useful tool to the technical teacher.

Tillotson (1984) examined the effect of instruction in spatial visualization on spatial abilities and mathematical problem solving. This study investigated the nature of spatial visualization and correlated it to problem solving performance. The Card Rotation, Cube Comparison, and Punched Holes aptitude tests were administered to 102 students in order to measure their current spatial ability. Tillotson provided problems to the students which were equally divided between spatial, analytical, and spatial analytical. Tillotson also provided the students with 10 weeks of spatial visualization instruction.

In the conclusions of this study, Tillotson found that spatial visualization is a good predictor of general problem solving ability. It was reported that the highest correlation occurred with the analytical subset of problems. Tillotson's observation was that high spatial ability may compensate for low analytical ability, but low spatial skills are not as easily compensated for with high analytical skills. Lastly, she found that students experienced significant gains in spatial ability with no significant correlative gain in problem solving ability.

Yaghi (1986) examined the question: To what extent do pictures and graphics affect learning new concepts and recognizing relationships? He reasoned that pictures and graphics are extensively used in textbooks and other instructional media and that previous research had dealt almost exclusively with the difference in effectiveness between colored and black and white pictures. For this study, two types of pictures were designed and constructed. The first was attentional, which is to attract the attention of the reader to the instruction and the second type was explicative, which is to explain the instruction in visual terms. Each problem set consisted of text and one each of the picture types.

After the 178 students in the sample received treatment consisting of different combinations of text and pictures, they were tested for understanding. With tests requiring memorization and relationships recognition, Yaghi concluded that explicative pictures enhanced performance in non-fictional materials and that attentional pictures were best used in story or fiction books.

Pandiscio (1994) studied spatial visualization relative to mathematics achievement. He was investigating a theoretical relationship between mental rotation of visually presented objects and proficiency in certain geometric tasks. Although Pandiscio found two significant correlations, the results did not support the original hypothesis that spatial ability is a strong predictor of achievement in geometry. Based on that finding, he recommended research which would follow alternative avenues of investigation relative to acquiring knowledge about learning and achievement in mathematics.

Lennon (1995) examined correlations of spatial visualization, spatial orientation, and flexibility of closure activities with achievement in microbiology. Lennon reported that these same abilities had previously been correlated with achievement in other science courses. The measures of achievement included overall course grade, final examination grade, and laboratory grade. With a sample of 158 students, Lennon found significant correlations among the variables. He analyzed data from the Cube Comparison Test of Spatial Orientation, the Paper Folding Test of Spatial Visualization, and the Surface Development Test of Spatial Visualization using stepwise multiple linear regression.

Reading Ability as a Predictor of Success

"Although people have read, and have taught other people to read for over 5,000 years, serious scientific research on the reading process has been conducted only during the last 100 years" (Orasanu, 1986, p. 1). Pearson, Barr, Kamil, and Mosenthal (1984) found that over 1000 published reading research reports are summarized annually. These studies come from around the world. The quantity of reading research being done suggests that any literature review will be outdated to some extent by the time it finds its way into print. However, this author will review related literature for research which has been done in order to predict success, while only briefly examining reading research in the broader context.

While the history of reading research by itself is fascinating, it is also one of little practical progress. The history is of little practical purpose because so little of it explains how people understand or comprehend what they read. Orasanu (1986) said, "Comprehension is the purpose of reading, yet far too little is known about the knowledge and conceptual organization needed for advanced reading competence" (p. xi). Regardless of what is read, understanding or comprehension of what has been read is a key element in successful reading. Smith (1994) stated that knowledge of the relevant language and subject matter is essential for reading comprehension.

"Throughout history, most reading instruction . . . has been based on the alphabetic principle: Letters stand for sounds; sounds can be combined into words" (Orasanu, 1986, p. 1). Words are then combined into sentences with sentences being combined into paragraphs. The historical assumption in reading research has been that comprehension somehow takes place automatically as the reader proceeds letter by letter to unlock the sounds and then combine them into words which are then strung into sentences and paragraphs. This view has readers plodding letter-by-letter, sound-by-sound, and word-by-word through a text.

Modern research indicates that language begins with the sentence and this is the unit of language everywhere. Recent research has found that the dominant alphabetic and phonetic theory of the reading comprehension process may be flawed and that comprehension is based on a reader's background knowledge. Early in the twentieth century, reading researchers ascertained that the learning of new material was aided by knowledge already acquired. In other words, a reader constructs a sensible interpretation of what is written on the page and he or she creates meaning based on the text which is being read. Smith (1994) stated, "meaning is not contained within the sounds of speech or the printed marks of writing, conveniently waiting to be discovered or decoded, but rather must be provided by the listener or reader" (p. 25).

Smith (1994) wrote, when we read, the brain receives visual information from the print. However, the information that we already have may be called nonvisual information. This is the prior knowledge. "Reading always involves a combination of visual and nonvisual information. It is an interaction between a reader and a text" (Smith, 1994, p. 67).

This understanding of interpreting new concepts by means of previously known concepts led to the development of modern reading assessment instruments (Pearson et al., 1984, p. 14). The notion of schemata being built from past experience is critical. Orasanu (1986) notes that early reading researcher, F. C. Bartlett "maintained that specific memories are reconstructed at the occasion of recollection on the basis of schemata" (p. 31). Assessment testing became more important, as it was determined that reading was not a passive, mechanical process. Rather it is a highly active process involving the same sort of organization and analytic action of ideas as occur in thinking at a higher order.

The measurement of reading ability is muddied by the fact that an author has intentions and represents those intentions in his or her text. The reader's understanding is dependent upon how much and what he or she has comprehended based upon previous experiences. Lastly, one must address the question: Does that reading lead to an appropriate action based on what has been written and read? The integrated complexity of a technical drawing book is certainly impacted by the questions raised by reading researchers.

Comprehension or understanding of a technical text may be enhanced when accompanied by relevant graphic images. However, reading comprehension may hinge on the content field specificity of the written text, regardless of graphic illustrations. Further, reading is a skill requiring continuous intersensory integrations. It requires the integration of visual information with information garnered from other senses (Hurley, 1965).

Although numerous studies were found which examined reading ability relative to disabled learners and adult learners, the review produced only a single study which was closely related to this study. Brownrigg (1962) examined reading ability and drafting achievement. He studied the reading abilities of college drafting students compared with the readability of drafting textbooks and with informational achievement in drafting. He found that the difficulty of the vocabulary played a greater role in understanding than did sentence length. Brownrigg concluded that the readability of the text must be at a slightly lower level than the mean reading level of the students and that the range of difficulty of the textbook is an important factor to consider when comparing texts. Further, he concluded that informational achievement in drafting and reading ability have a substantial positive relationship.

Spatial Visualization Ability and Reading Ability
as Predictors of Success for Technical Drawing

As discussed earlier, a number of researchers, including Laughton (1977), Patwell (1992), and Hosterman (1994), have examined the relationships between spatial visualization ability and reading ability as they relate to the learning disabled and adult learners. However, the vast majority of this research has confined itself to learners within the traditional kindergarten through twelfth grade educational system. As a result of this literature search, there appears to be no definitive research which has been conducted at the community college level using reading ability and spatial visualization ability as predictors of success for technical drawing.

The studies cited above do not warrant individual examination or inclusion relative to this study, although individually they may provide insight into the relationship between reading and spatial visualization ability for the non-learning disabled or non-adult learner.

Several studies were examined and are discussed below. Their inclusion was based on the fact that they asked questions relative to the reading and spatial ability variables used in this study.

Wardle (1975) examined the predicted versus actual contribution of science textbook illustrations to pupil reading comprehension. Five treatment conditions were established including: a science text accompanied by an illustration which answered a high number of test questions, a science text accompanied by an illustration which answered a medium number of test questions, a science text accompanied by an illustration which answered a low number of test questions, an unillustrated text, and a control group which was given the test without text or illustration. After completing the reading assignment lessons, students were given a test of 20 questions. Each lesson provided sufficient material to answer the questions and students were able to consult their lesson materials when completing tests. The major finding of Wardle's study was that students did not perform significantly better on reading comprehension tests when provided with illustrated or unillustrated lessons.

Coleman (1983) studied the effects of graphic organizers, text organization, and reading ability on the recall of text information. Specifically, this study attempted to clarify conditions under which the graphic organizer would be expected to facilitate the learning of text information. Coleman found that the graphic organizer facilitated recall for high ability readers under certain conditions. Results of the study indicate that the graphic organizer is an efficient instructional strategy which facilitates the comprehension and memory of text information for these students. Implicit in these findings are opportunities for future research and educational practice.

Summary

In the review of related literature, it is evident that there has been an ongoing search to identify success factors relative to technical drawing. However, almost without exception, the researchers which have been cited, have recommended further study. Further, they have recommended that there is a definitive need to examine variables which lead to more conclusive results than has been found previously. Cumulatively, these studies suggest that very little conclusive evidence exists to readily predict student success in technical drawing. This suggestion is supported by the fact that numerous authors have recommended that further study be conducted to identify factors which better predict success.

Borg, Gall, and Gall (1993) state that the goal of prediction studies is to seek out those predictor variables that best correlate with the criterion variable. Further, they say that aptitude measures that are shown to relate to later performance or achievement can be used for a variety of practical educational purposes.

It is suggested that technical drawing synergistically combines the reading and spatial visualization abilities equation in a way in which other disciplines do not. The technical drawing student has an immediate opportunity to demonstrate understanding of both the written text and its graphical interpretation in timely and practical applications. Therefore, reading and spatial visualization abilities should be the optimal predictor variables in a study to predict success in technical drawing.

Based upon the review of related literature, this study examined a unique and synergistic application of these abilities in a relevant context. Further, this study examined previously unexplored relationships while making a substantial contribution to the empirical knowledge base of the cumulative research presented above. By studying the relationships between reading and spatial visualization ability as predictors of success for technical drawing, previously unexplored questions may be addressed and answered.

CHAPTER 3

METHODOLOGY, PROCEDURE, AND RESEARCH DESIGN

Introduction

The methodology, procedure, and research design selected for this study is described below. A description of both the population and cluster sample is provided, in addition to a description of standardized assessment instruments, including those individual assessment instruments which were administered, and a description of the statistical procedures which were utilized in regard to the data collected for this study.

The Population and Sample of the Study

The population for this study was considered to be all students attending Hawkeye Community College. A cluster sample selection method was used to identify the participating students for the study. "In cluster sampling the unit of sampling is not the individual but rather a naturally occurring group of individuals" (Borg et al., 1993, p. 98).

Cluster sampling was used for this study because it was more feasible to select groups of individuals than to select individuals from the defined population. Cluster sampling "is often used in educational research, with the classroom as the unit of sampling" (Borg et al., 1993, p. 98). The cluster sample for this study was composed of Hawkeye Community College students who self-selected enrollment in a traditional first semester introductory technical drawing course during the Fall 1996 semester.

In regard to the cluster sample, initially, 59 students enrolled in the introductory technical drawing course and thus became the sample. The students were majoring in programs of study found within the Engineering and Technology Department of Hawkeye Community College. The students were enrolled as majors within the Architectural Construction Technology, Civil and Construction Engineering Technology, Drafting and Design Technology, and Mechanical Engineering Technology programs of study. It is noted that the traditional introductory technical drawing course is a requirement of graduation in each of these programs of study.

Standardized Assessment Instruments

Reliability and validity are two elements that serve as the backbone of any standardized assessment instrument. Ary, Jacobs, and Razavieh (1990) said, "The reliability of a measuring instrument is the degree of consistency with which it measures whatever it is measuring" (p. 268). Further, reliability is the capacity of an instrument to produce consistent or repeatable results, regardless of who administers it and a reliable assessment instrument is designed to be of sufficient length as to provide a sound basis for drawing inferences about an individual's abilities. Reliability also refers to the accuracy and precision of a test and is an indication of the confidence one may place in a test score.

Validity "is concerned with the extent to which an instrument measures what one thinks it is measuring" (Ary et al., 1990, p. 256). An instrument is valid when it measures what it is claiming to measure and it is understood that validity is always specific to the particular purpose for which the assessment instrument is being used.

Three types of validity are considered relative to standardized assessment instruments. They are: content-related validity, criterion-related validity, and construct-related validity.

Content-related validity "shows the extent to which the sample of items on a test are representative of some defined universe, or domain of content" (Ary et al., 1990, p. 257). For example, a skills-achievement test has content validity if it contains questions that measure the knowledge and skills an individual would be expected to perform, i.e., the test includes a representative sample of tasks, behaviors, and knowledge necessary to perform a job.

Criterion-related validity "shows the extent to which the scores on a measuring instrument are related to an independent external variable (criterion) believed to measure directly the behavior or characteristic in question" (Ary et al., 1990, p. 259). Criterion-related validity measures whether a test would predict success or failure, i.e., the test addresses the inference that individuals who score better on tests will be successful on some criterion of interest. There are several characteristics that a criterion measure should possess, including relevance, reliability, and freedom from bias. It is critical that a test used for selection and classification purposes exhibit criterion-related validity.

Construct-related validity "focuses on the test scores as a measure of a psychological trait or construct" (Ary et al., 1990, p. 261). A construct is theoretical and refers to something that is not itself directly measurable but that explains observable effects. Therefore, if a test is measuring skills that are observable, construct validity is not usually necessary.

The difference between reliability and validity becomes clear in the following analogy. If we attempt to use a wooden yardstick to measure metric distances, the yardstick is consistently accurate at what it does, i.e., it is reliable; however, it is invalid since it measures the wrong thing. In examining each of the assessment instruments to be used in this study, each was found to be both reliable and valid as presented in detail below.

Revised Minnesota Paper Form Board Test

The first standardized assessment test administered to the sample was the Revised Minnesota Paper Form Board Test (RMPFBT) Series AA which tests a student's spatial visualization ability. The RMPFBT is an ability or aptitude test in that the function of the test is to make inferences regarding a person's ability or aptitude for future learning. The RMPFBT was administered during the second week of October 1996. The students' tests were scored and the raw scores were calculated and converted to normed data percentile values during the first week of January 1997. Raw score to normed data percentile value conversion tables were supplied by The Psychological Corporation. Information relative to individual student outcomes are presented in Appendix A.

The original Minnesota Paper Form Board Test was published by the University of Minnesota Press in 1930. The test was part of an extensive study of the measurement of mechanical ability conducted by Paterson, Elliot, Anderson, Toops, and Heidbreder.

The revised test was published by Rensis Likert and W.H. Quasha in 1934. The Psychological Corporation completed a comprehensive revision of the RMPFBT and related normed data in 1995. The RMPFBT was purchased from The Psychological Corporation, which is a wholly-owned subsidiary of Harcourt Brace and Company.

The Psychological Corporation and others, including Carpenter and Just (1986), Lohman (1986), Pelligrino and Kail (1986), Thayer (1985), and Poltrock and Brown (1984), have conducted extensive and ongoing validity and reliability testing relative to the RMPFBT and spatial ability. The Kuder-Richardson Formula 20 (KR20) has been used to measure internal consistency of the RMPFBT instrument. The KR20 has been measured at .85 to .95 depending upon the study and normed data group being examined. The RMPFBT has been used successfully for over 60 years to measure spatial abilities.

The multiple forms of this instrument are identified as Series AA and BB. Series AA was administered to the sample. The RMPFBT is a 20 minute timed test that uses geometric shapes to assess capacity to visualize. It consists of 64 two-dimensional diagrams depicted as cut into separate pieces. The diagrams increase in difficulty toward the end of the test. Therefore, the RMPFBT takes advantage of both speed and power. Speed tests are composed of relatively easy items and rely on restrictive time limits to differentiate among examinees. Power tests, on the other hand, rely on item difficulty to discriminate between examinees.

For each of the 64 diagrams, there are five figures with lines indicating the different shapes out of which they are made. From these five choices, the examinee must accurately visualize the separate pieces as a whole geometric shape and he or she chooses the one figure that is composed of the exact parts that are shown in the original diagram.

The test was developed to measure those aspects of mechanical ability or aptitude requiring the capacity to visualize and manipulate objects in space. This ability, known as spatial ability, may be regarded as one aspect of intelligence. The individual who scores high in spatial ability tends to perform well on tasks requiring the mental transformation, manipulation, and analysis of two- and three-dimensional objects.

Scoring of the RMPFBT Series AA and BB tests includes a correction for guessing. A student's raw number corrected score is obtained by subtracting one-fifth of the incorrect responses or wrongs from the total number of correct responses or rights. If the proportion of incorrect responses (wrongs) yields a whole number and a fraction, the fraction is dropped if it is two-fifths (.4) or less; the whole number is increased by one if the fraction is three-fifths (.6) or greater. Items which are omitted have no impact on the raw corrected score.

Each raw corrected score was converted to one of 23 designated percentile values as found in the normed data tables provided by The Psychological Corporation in the second edition of the Revised Minnesota Paper Form Board Test Manual (Likert & Quasha, 1995). Each percentile value represents the midpoint of a zone, or band, of ability. In most cases, the zones are five percentile units wide. However, the zones differ at the extremes; a percentile rank of 5 includes percentile ranks 4 through 7; a percentile rank of 3 includes 2 and 3; and a rank of 1 includes the first percentile only. Similarly, the 95th percentile includes ranks of 93 through 96; 97 includes 97 and 98; and 99 includes only the 99th percentile.

Tests of Adult Basic Education: Reading Subtest

The second standardized assessment test administered to the sample was the reading subtest from the Tests of Adult Basic Education (TABE) Complete Battery. The TABE reading subtest measures a student's reading ability and grade level reading ability. The TABE is an ability or aptitude test in that the function of the test is to make inferences regarding a person's ability or aptitude for future learning. The TABE reading subtest was administered during the second week of November 1996. The students' tests were scored and the raw scores were converted to normed percentile values during the first week of January 1997. Raw score to normed percentile value conversion tables were supplied by CTB/McGraw-Hill, a division of the Educational and Professional Publishing Group of The McGraw-Hill Companies, Incorporated. Information relative to individual student outcomes are presented in Appendix B.

The test instruments were purchased from CTB/McGraw-Hill. The multiple forms of this instrument are identified as Forms 7 and 8, Level A. The TABE reading subtest, Form 7 Level A, was administered to the sample. This test has a grade level reading ability measurement range from 0.0 through 12.9. A grade equivalent score indicates the grade and month in school at which an average student would perform about as well as the test taker has performed.

To ensure an accurate description of test performance, an Item Response Theory (IRT) model was employed by McGraw-Hill in the selection and scaling of items within the TABE Form 7 and 8 tests. The IRT model takes into account information such as discrimination, difficulty, and guessing. The aim of this functional-level test is to obtain the most reliable diagnosis of an examinee's basic-skills achievement level. Optimal information relative to the examinee is achieved when the examinee answers in the range of 40 to 75% of the items correctly. Scores at the lower or higher end of the scale will have less diagnostic value.

CTB/McGraw-Hill has conducted extensive and ongoing validity and reliability tests relative to the complete battery including the reading subtest. As stated in the Tests of Adult Basic Education Technical Report 91489 (1996),

> Validity refers to the appropriateness, meaningfulness, and usefulness of the specific inferences made from the test scores. Test validation is the process of accumulating evidence to support such inferences. The compilation of multiple sources of validity evidence supports the construct validity of TABE 7 & 8. (p. 3)

The Kuder-Richardson Formula 20 (KR20) has been used to measure internal consistency of the TABE instrument. It is understood that the higher the KR20 coefficient, the greater the internal consistency of the subtest level. Relative to Form 7 and 8, Level A, the KR20 has been measured at .89 to .93 depending upon which study and normed data group is being examined.

The reading subtest measures basic reading skills in a variety of contexts. In addition, the test measures vocabulary skills as part of the reading process. The content also includes items which measure both prose and document literacy, as well as measuring the ability to find and use information. The TABE reading subtest consists of 50 items requiring a timed testing period of 50 minutes. The test objectives include measures for the student's interpretation of graphic information (10 items), understanding of words in context (5 items), recall of information (5 items), understanding of construct meanings (15 items), and the evaluation and extension of meaning (15 items).

Individual student diagnostic profiles were completed using each categorical test item as either correct or incorrect to show mastery, partial mastery, or nonmastery in each of the five subtest objective categories. Mastery of an objective required that 75% or more of the responses given in a category were correct, while partial mastery of an objective required that 50% or more of the responses given were correct.

National Occupational Competency Testing Institute:

Job Ready/Student General Drafting and Design Written Assessment

The third standardized assessment test administered to the sample was the National Occupational Competency Testing Institute (NOCTI) Job Ready/Student General Drafting and Design written assessment. The NOCTI test was used to determine the students' competence level in technical drawing. The NOCTI test is an achievement test in that its function is to record present or past accomplishments of the student. The test measured the extent to which the student had already achieved something, acquired certain information, or mastered certain skills. The test was administered during the second week of December 1996. The students' tests were scored and the raw scores were converted to normed percentile values during the first week of January 1997. Raw score to normed percentile value conversion tables were supplied by the National Occupational Competency Testing Institute. Information relative to individual student outcomes are presented in Appendix C.

The NOCTI test instruments and evaluation services were purchased from the National Occupational Competency Testing Institute. The written assessment consisted of 173 questions which covered 8 areas of understanding in general drafting and design. The written test was a timed test requiring 3 hours to complete. Forty percent of the test questions were related to traditional mechanical drafting. Sixteen percent deal with basic drawing skills. Twelve percent of the questions cover systems drafting. Nine percent of the questions were related to the introduction to drafting, while 8% elicit responses relative to preparing to draw. Architectural drafting and calculations used in drawing were each represented by 6% of the questions in the assessment. Lastly, 3% of the questions were related to drafting with machines.

It is noted for the reader that NOCTI also provides a performance component which requires a timed three hour completion period. The performance test consists of seven drawing exercises. The sample of this study did not take the performance test.

Due to the fact that the researcher purchased only the testing and evaluative services, rather than the test instruments themselves, there is but a single source for reliability data in regard to the instrument. NOCTI has used the KR-20 reliability measure for the general drafting and design assessment. The reliability measure for the Job Ready/Student General Drafting and Design written assessment is .95 based upon a sample size of 472 subjects who have completed the examination after a comprehensive revision and publication in 1996.

Statistical Methodology and Analyses of Data

The primary data analysis tool used in this research study was the Pearson Product-Moment Coefficient of Correlation (r) which is the most stable bivariate correlational statistic (Borg et al., 1993). Israel and Wright (1987) state that "the Pearson r is the most powerful correlational tool available" (p. 160). It is also "the most commonly used correlation index" (Ary et al., 1990, p. 149). "The presence of regularity among pairs of X and Y scores indicates that the variables are related" (Witte, 1989, p. 132).

The estimate of significance relative to the Pearson Product-Moment Coefficient of Correlation was determined by knowing three factors. Those factors were: (a) the number of individual subject observations, (b) the number of measurable variables involved, and (c) the level of statistical confidence which was desired. Although 59 subjects comprised the sample initially, only 38 subjects within the cluster sample completed the three assessments during the Fall 1996 semester.

The data were examined at the .05 level of significance with a critical value of r, providing the threshold number for significance. The critical r value at the .05 level of significance using a nondirectional (two-tailed) test was calculated to be .3206 using two-degrees of freedom (Ary et al., 1990, p. 515). It is recognized that this critical value varies slightly as a function of the critical r value table which is used. However, this variation is minimal. A calculated r value which exceeds this critical threshold will indicate that the correlation is significant at the .05 level and therefore not due to chance alone.

Best and Kahn (1986) state that the magnitude of the r value suggests the strength or degree of the relationship between the variables. An r value of .00 to .20 represents a negligible relationship, while a low level relationship is suggested when r is .20 to .40. A moderate relationship exists when the r value is .40 to .60. With an r value of .60 to .80, there is a substantial relationship and an r value of .80 to 1.00 suggests a high to very high correlational relationship.

First, the data resulting from the administration of the RMPFBT spatial visualization ability test and the NOCTI drafting and design achievement test were used to calculate a Pearson Product-Moment Coefficient of Correlation between these two variables. Second, the data resulting from the administration of the TABE reading ability test and the NOCTI drafting and design achievement test were used to calculate a Pearson Product-Moment Coefficient of Correlation between these two variables. The calculated r values are presented in Chapter 4.

After the correlation coefficients were calculated, the Pearson-r values were squared, which provided the coefficients of determination (Ary et al., 1990, p. 153). "The value of r^2 supplies us with a direct measure of the strength of a relationship" (Witte, 1989, p. 127).

Best and Kahn (1986) stated,

> The variance of the measure that we want to predict can be divided into the part that is explained by, or due to, the predictor variable and the part that is explained by other factors (generally unknown) including sampling error. (p. 240)

The calculated $\underline{r}^2$ explains that part of the students' technical drawing achievement which is due to the individual predictor variable. The calculated $\underline{r}^2$ values are presented in Chapter 4.

Upon completion of the bivariate correlational calculations, a secondary data analysis tool was employed. This portion of the study dealt with multivariate correlational analyses of the data, including the derivation of a data-based multiple regression prediction equation. The data representing the students' reading ability and their spatial visualization ability were assessed relative to their cumulative predictive ability using multiple regression analysis. "Multiple regression is probably the most commonly used of the multivariate correlational statistics" (Borg et al., 1993, p. 267-268). It is "used to determine the multiple correlation coefficient ($\underline{R}$) between a criterion variable and a combination of two or more predictor variables" (Borg et al., 1993, p. 268).

Relative to this study, the RMPFBT spatial visualization ability normed test scores and the TABE reading ability normed test scores were identified as the independent or predictor variables, while the NOCTI technical drawing achievement normed test score was identified as the dependent or criterion variable. In the future, the derived multiple regression prediction equation could be used with similar groups of students when only the independent variables are known. The equation would then predict the criterion variable--the students' achievement in technical drawing.

When multiple regression analysis techniques are used, "the statistical procedure weights each predictor so that the predictor variables in combination give the optimal prediction of the criterion" (Ary et al., 1990, p. 395). In multiple regression analysis, "the complex equation still qualifies as a least squares equation, since it minimizes the sum of the squared predictive errors" (Witte, 1989, p. 154).

All data analyses were completed using the Statistical Package for the Social Sciences (SPSS) software. Through the use of this software, numerous combinations of the variables and the elements within the variables could be examined efficiently and effectively for presentation in Chapter 4.

Summary

A cluster sample of 38 students were given assessment tests which measured their reading ability, spatial visualization ability, and technical drawing achievement. The purpose of the assessments was to determine the strength of the bivariate and multivariate correlational relationships between and among the variables. Data analyses were facilitated through the use of SPSS software.

The primary data analysis tool used in this research study was the Pearson Product-Moment Coefficient of Correlation ($\underline{r}$). The data were examined at the .05 level of significance, with a critical $\underline{r}$ value of .3206 providing the threshold of significance.

Borg et al. (1993) stated,

> A relationship study is meaningful whether the correlation coefficient obtained is low or high, positive or negative. Any size correlation coefficient contributes to our understanding of the educational phenomena involved. Therefore, the practical significance of the correlation coefficient is not important. (p. 271)

However, this is not to say that the correlation does not have practical significance.

At the second level, this relationship study became a prediction study using the multiple correlation coefficient (R). The purpose was to be able to predict or forecast future students' achievement in technical drawing, based upon their assessed reading and spatial visualization abilities, using the general form of the multiple regression prediction equation.

> In prediction studies we are concerned not only with the statistical significance of the correlation coefficient but also with its practical significance. If the coefficient is sufficiently large to achieve statistical significance, we can be fairly confident that this is not a chance result. If the coefficient is sufficiently large to have practical significance, it means the measure, or measures, used to predict an outcome may be useful for improving educational practice. (Borg et al., 1993, p. 271)

As a result of this two-tiered study, a better understanding was gained of the contribution of a student's reading and spatial visualization abilities to the more complex characteristic--technical drawing achievement. This study was conducted to gain additional insight into the nature of this complex characteristic, as well as to predict students' success in it.

CHAPTER 4

ANALYSES, PRESENTATION, AND DISCUSSION OF DATA

Introduction

The data collected from the cluster sample (N) of 38 students who completed the three standardized assessment instruments during the Fall 1996 semester while enrolled in a traditional, introductory technical drawing course at Hawkeye Community College are presented and analyzed below. Data analyses relevant to the research questions are presented in table form with descriptions and discussion provided. Information relative to individual student outcomes are presented in Appendix A for the RMPFBT, in Appendix B for the TABE, and in Appendix C for the NOCTI assessment. All data analyses were completed using the Statistical Package for the Social Sciences (SPSS). This software facilitated the efficient and effective examination of numerous combinations of the variables and the elements found within those variables.

Bivariate Correlational Analyses: Using the Pearson Product-Moment Coefficient of Correlation (r)

This portion of the research study was designed to answer research questions 1 and 2. The data resulting from the students' RMPFBT spatial visualization ability assessment and their NOCTI drafting and design achievement assessment were used to calculate a Pearson Product-Moment Coefficient of Correlation (r) between the two variables. In addition, the data resulting from the students' TABE reading subtests and their NOCTI drafting and design assessments were used to calculate a Pearson Product-

Moment Coefficient of Correlation (r) between these two variables. The calculated coefficient of correlation (r) suggests the strength or degree of the relationship between the variables. The calculated coefficient of determination (r^2) provides a direct measure of the strength of the relationship between the students' spatial visualization ability, reading ability, and technical drawing achievement.

As was stated in Chapter 3, the data were examined at the .05 level of significance, with a critical value of r calculated to be .3206. A calculated r value exceeding this critical threshold would indicate that the correlation between any 2 variables is significant at the .05 level. The bivariate correlational data analyses for the cluster sample (N), showing the correlative relationships between the students' spatial visualization ability and reading ability to their technical drawing achievement is presented in Table 1.

As can be seen in Table 1, the calculated correlation coefficient r between students' reading ability and their technical drawing achievement was .3833. This value exceeds the critical r value of .3206, indicating that the relationship between these variables is statistically significant at the .05 level. The calculated coefficient of determination r^2 between students' reading ability and their technical drawing achievement was .1469. This value means that 14.69% of the variance in students' technical drawing achievement is explained by their reading ability, while the remainder is explained by other factors.

The calculated correlation coefficient r between students' spatial visualization ability and their technical drawing achievement was .1166, which is below the threshold of significance. The calculated coefficient of determination r^2 between students' spatial visualization ability and their technical drawing achievement was .0136. This value means that only 1.36% of the variance in students' technical drawing achievement is explained by their spatial visualization ability.

The calculated correlation coefficient r between the students' reading and spatial visualization ability was .2716, which is below the threshold of significance. Conclusions and recommendations relative to these analyses are presented in Chapter 5.

Table 1

Bivariate Correlational Analyses of Students' Spatial Visualization Ability, Reading Ability, and Technical Drawing Achievement

	Spatial Ability (RMPFBT)	Reading Ability (TABE)	Drawing Achievement (NOCTI)
Spatial Ability (RMPFBT)	1.0000	.2716	.1166
Reading Ability (TABE)	-------	1.0000	.3833*
Drawing Achievement (NOCTI)	-------	-------	1.0000

Note. $N_{sample} = 38$ df = 2 *$p < .05$

Multivariate Correlational Analyses:

Using the Multiple Correlation Coefficient (R)

This portion of the research study was designed to answer research question 3. When more than two variables are being investigated, as was the case in this study, a multivariate correlational statistical technique is used to determine the cumulative degree of relationship among the variables. In this study, the multiple regression statistical technique was used. Multiple regression analysis was used to determine the multiple correlation coefficient (R) between a criterion variable and a combination of two or more predictor variables.

Relative to this study, the students' RMPFBT spatial visualization ability assessment and their TABE reading ability assessment were identified as the independent or predictor variables, while the students' NOCTI technical drawing achievement test was identified as the dependent or criterion variable. The multiple regression statistical procedure mathematically weights each predictor so that the predictor variables in combination give the optimal prediction of the criterion.

The calculated multiple correlation coefficient (R) suggests the strength or degree of the relationship among the variables. The calculated multiple coefficient of determination (R^2) provides a direct measure of the strength of the relationship among the students' spatial visualization ability, reading ability, and their technical drawing achievement.

The multivariate correlational data analyses for the cluster sample (N), showing the relationships among the students' spatial visualization ability, reading ability, and their technical drawing achievement is presented in Table 2. A multiple regression prediction equation, showing the cumulative strength of the relationship among the students' spatial visualization ability and their reading ability relative to their achievement in technical drawing was also derived from the data. The data were examined at the .05 level of significance.

Table 2

Multivariate Correlational Analyses of Students' Spatial Visualization Ability, Reading Ability, and Technical Drawing Achievement

Criterion Variable:	Technical Drawing Achievement
Predictor Variables:	Spatial Visualization Ability and Reading Ability

	Analysis of Variance		
Source	df	Sum of Squares	Mean Square
Regression	2	4,650.69	2,325.34
Residual	35	26,963.40	770.38

Note. $N_{sample} = 38$

Multiple $R = .3835$ F value = 3.0184

Multiple $R^2 = .1471$ Sig. $F = .0618$

As seen in Table 2, the calculated multiple correlation coefficient R among students' spatial visualization ability and reading ability, and their technical drawing achievement was .3835. The calculated multiple coefficient of determination R^2 was .1471. This value means that 14.71% of the variance in students' technical drawing achievement is explained by their spatial visualization ability and reading ability, while the remainder is explained by other factors. The significance of the F value was .0618, which means that the multiple regression relationship was not significant at the .05 level. Conclusions and recommendations relative to these analyses are presented in Chapter 5.

Table 3 presents the calculated multiple regression prediction equation data relative to the relationship among the students' spatial visualization ability and reading ability to their achievement in technical drawing. The criterion variable (Y') and the two predictor variables (X_1 and X_2) are identified, as are the constant (a) and the standardized regression weights (b_1 and b_2) for each of the predictor variables. For the reader's information, the multiple regression prediction equation was used in its general form as shown in Chapter 3.

Using the multiple regression prediction equation in its general form relative to the criterion and predictor variables of this study, we have:

$$Y' = a + b_1X_1 + b_2X_2.$$

Table 3

Multiple Regression Prediction Equations: Analyses of Students' Spatial Visualization Ability, Reading Ability, and Technical Drawing Achievement

Criterion Variable:	Technical Drawing Achievement
Predictor Variables:	Spatial Visualization Ability (X_1) and Reading Ability (X_2)

Variable	Regression Analyses B	SE B	β (Beta)	T	Sig. T
Step 1					
Reading Ability (TABE) X_2	.889490 (b_2)	.357198	.383328	2.490	.0175*
Constant (a)	-21.395946	29.011618	---------	-.737	.4656
Step 2					
Spatial Ability (RMPFBT) X_1	.018822 (b_1)	.226890	.013456	0.083	.9344
Reading Ability (TABE) X_2	.881010 (b_2)	.376380	.379673	2.341	.0251*
Constant (a)	-22.067437	30.513509	---------	-0.723	.4744

Note. $N_{sample} = 38$

R^2 =.14694 (Sig. F = .0175) for Step 1;

ΔR^2 = .14711 (Sig. F = .0618) for Step 2

Substituting the calculated values from Table 3, the derived equation for predicting student technical drawing achievement based upon the assessed spatial visualization ability and reading ability of the student is found to be:

$$Y' = (-22.0674) + 0.0188\ (X_1) + 0.8810\ (X_2).$$

Conclusions and recommendations relative to these analyses are presented in Chapter 5.

Summary

The data gathered from the cluster sample of 38 students were presented and analyzed based upon the assessment tests administered during the Fall 1996 semester at Hawkeye Community College. The data were presented in tables showing the bivariate and multivariate relationships between the students' spatial visualization ability, reading ability, and technical drawing achievement.

The bivariate correlational analyses were done using the Pearson Product-Moment Coefficient of Correlation (r) to determine the strength of the relationship between the students' spatial visualization ability and their technical drawing achievement. In addition, the Pearson-r was used to determine the strength of the relationship between the students' reading ability and their technical drawing achievement. The computational formula was used to calculate the r values. Based upon these calculated r values, the coefficients of determination (r^2) were also calculated.

In the multivariate correlational analyses, the multiple correlation coefficient (R) and multiple coefficient of determination (R^2) were used to determine the strength of the relationships among the students' spatial visualization ability, reading ability, and technical drawing achievement. Lastly, the multiple regression prediction equation was used in its general form to mathematically show the relationship of the criterion variable (Y') which was technical drawing achievement, and the two predictor variables (X_1 and X_2) which were the students' spatial visualization ability and reading ability respectively. The equation constant (a) and the standardized regression weights (b_1 and b_2) for each of the predictor variables were also shown. All of the study data were analyzed using SPSS software.

Findings were discussed following each data presentation table while detailed conclusions and recommendations relative to these findings are presented in Chapter 5. A major finding was that a statistically significant relationship existed between the students' assessed reading ability and their technical drawing achievement.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The basis of any research study is to identify a problem, collect, report, and analyze data, draw conclusions from the findings, and to then make recommendations based upon those conclusions (Clover & Balsley, 1984). In addition, it is known that no research can be truly conclusive without constant revision and scrutiny. Although this study has been brought to closure within the boundaries of this chapter, this author will continue to conduct research in regard to students' spatial visualization ability, reading ability, and their achievement in technical drawing. Chapter 5 includes the following headings: (a) Summary of the Study, (b) Conclusions of the Study, and (c) Recommendations for Further Study.

Summary of the Study

The problem of this exploratory study was to determine the strength of the bivariate correlational relationship between introductory technical drawing students' assessed spatial visualization ability and assessed reading ability to their assessed achievement in technical drawing. This was done using the Pearson Product-Moment Coefficient of Correlation (r). Further, the problem of this study was to determine the strength of the multivariate correlational relationship among these same variables using the Multiple Correlation Coefficient (R). Lastly, a multiple regression prediction equation was derived from the stepwise multiple regression analyses of data.

The purpose of the study was to provide community college technical drawing instructors, career counselors and advisors with an advising and placement tool which could be used to assess students' abilities when they are seeking entrance into technical programs of study. This assessment could minimize failure and the loss of time occasioned by false starts in inappropriate technical curricula for the individual student.

The cluster sample of 38 students were given three separate assessments. The assessments which the students completed were, the Revised Minnesota Paper Form Board Test, the Tests of Adult Basic Education Complete Battery reading subtest, and the National Occupational Competency Testing Institute Job Ready/Student General Drafting and Design written test.

Three research questions were established for this study based upon the lack of conclusive research findings in the literature which would have lead to the development of directional hypotheses. First, the study determined the strength of the bivariate correlative relationship between the students' assessed spatial visualization ability and their assessed achievement in technical drawing. Second, the study determined the strength of the bivariate correlative relationship between the students' assessed reading ability and their assessed achievement in technical drawing. Third, the study determined the strength of the multivariate correlative relationship among the students' assessed spatial visualization ability, reading ability, and their assessed achievement in technical drawing. Lastly, a multiple regression prediction equation was derived from the data for future student assessments.

The data collected were first analyzed using the Pearson Product-Moment Coefficient of Correlation (r). The data were examined at a 95% confidence interval (.05 level of significance) with a critical value of r providing the threshold number for significance. The critical r value at the .05 level of significance using a nondirectional (two-tailed) test was calculated to be .3206. An r value exceeding this critical threshold indicated statistical significance at the .05 level, which would not be due to chance alone. The data were presented in tabular format with information and discussion provided as appropriate.

Upon the completion of the bivariate correlational analyses, secondary analyses of the data were undertaken. The students' assessed reading ability and spatial visualization ability were employed as independent or predictor variables to assess their cumulative predictive ability relative to their technical drawing achievement, which was the dependent or criterion variable used in a data-derived multiple regression prediction equation. Using the multivariate statistical technique of multiple regression, each predictor variable is mathematically weighted so that the predictor variables in combination give the optimal prediction of the criterion variable.

The findings of the study, based upon the presentation and analyses of data were provided in Chapter 4. The conclusions and recommendations of the study relative to these findings are presented below.

Conclusions of the Study

Based on the analyses of data gathered in this study and subject to the stated assumption and delimitation of this study, it was concluded in regard to Research Question 1, that the Pearson Product-Moment Coefficient of Correlation (r) between the students' assessed spatial visualization ability and their assessed achievement in technical drawing was .1166, which was not statistically significant at the .05 level. Further, it was concluded that in regard to Research Question 2, the Pearson Product-Moment Coefficient of Correlation (r) between the students' assessed reading ability and their assessed achievement in technical drawing was .3833, which was statistically significant at the .05 level. Lastly, it was concluded that in regard to Research Question 3, the Multiple Correlation Coefficient (R) among the students' assessed spatial visualization ability, assessed reading ability, and their assessed achievement in technical drawing was .3835, which was not statistically significant at the .05 level.

Therefore, it was reported that a statistically significant relationship existed between the students' reading ability and their technical drawing achievement. There was not a significant relationship between the students' spatial visualization ability and their technical drawing achievement. It was shown that approximately 15% of the variance in students' technical drawing achievement was attributable to their reading ability, while slightly more than 1% of the variance in the students' technical drawing achievement was attributed to spatial visualization ability. In regard to the Multiple Correlation Coefficient

(R), it was reported that a statistically significant relationship does not exist at the .05 level among these variables.

Recommendations of the Study

The following recommendations are based upon the review of related literature, data analyses, findings and conclusions of the study. Given the outcomes of this study, recommendations for further study are warranted and may be utilized to further define the relationship between students' spatial visualization ability, reading ability, and their achievement in technical drawing.

The recommendations for further study, made in regard to this study are:

1. It is recommended that this exploratory study be replicated using a larger cluster sample while using the same standardized assessment instruments which were used in this study.

2. It is recommended that a similar study be conducted within the community college system of Iowa or conducted within regional community college systems or conducted within the national community college system.

3. It is recommended that further study be performed using other standardized assessment instruments which measure students' reading and spatial visualization abilities, as well as their technical drawing achievement.

4. It is recommended that further study be performed to identify other relevant predictor variables for technical drawing achievement.

5. It is recommended, based upon the extensive literature review of this author, that further study be performed to compare and contrast or comprehensively delineate the chronological developmental history of the universal graphic language and the chronologically parallel development of language universally.

6. It is recommended that this exploratory study be replicated using a larger cluster sample, while using assessments which measure students' computer-based spatial visualization ability, reading ability, and computer-aided technical drawing achievement.

7. It is recommended that this exploratory study be conducted as an exploratory longitudinal study, using a cluster sample of students at the 8th, 10th, 12th, 14th, and 16th grade levels, while using multiple forms assessment instruments to measure baseline spatial visualization ability, reading ability, and technical drawing achievement, relative to actual ability and achievement gains made between testing cycles.

Epilogue

"Man learned to sketch thousands of years before he learned to write. His first letters were simplified drawings" (Coover, 1954, p. 41). The symbiotic and synergistic relationship between the spoken language and the universal graphic language has been observed for thousands of years. Pre-technical drawings were simple symbolic and graphical representations, but they were the mainstays of the earliest communication network. Drawings were the common conduit through which communication occurred. Everyone, regardless of their language, or lack of it, could understand drawings.

Drawings were a bridge between people and their different languages. Today, that bridge is called the universal graphic language--technical drawing.

Although, this author will not provide a complete chronology of the universal graphic language and its rich relationship to the spoken language, the reader is assured that the history has been documented, but sadly that history has been written in bits and pieces by hundreds of authors. From this author's extensive review of related literature, it was found that the relationship has been discussed in literally every text examined. In what is purported to be the first text published in the United States, William Minifie (1849) wrote,

> One workman is superior to another (other circumstances being the same) directly in proportion to his knowledge of drawing, and those who are ignorant of it must in many respects be subservient to others who have obtained that knowledge. (p. 5)

Minifie's statement rings as true today as it did in 1849 when he penned it. In an increasingly complex and highly technological society, an individual's ability to understand and comprehend--to read a text and a technical drawing--are critical skills to be acquired by the large majority of technicians, especially those that will become the "writers and readers" of technical drawings. The technical drawing student must demonstrate a high degree of spatial visualization ability and reading ability in order to optimize their achievement in technical drawing. The student must readily read the text, as well as its graphical translation. The students' spatial visualization and reading ability are opposite sides of the same "reading" comprehension coin.

In an educational setting, it may be readily observed that many students can think in one dimension, some few in two dimensions, but those that can think in three dimensions are exceedingly rare. The contemporary technician, either as a student or an employee, must demonstrate, on a daily basis, the ability to think in three dimensions--mentally manipulating, rotating, twisting, or inverting pictorially presented mental stimuli. The student must be able to simultaneously interpret or understand the context of both the printed word and its pictorial representation.

Students' with a low level of spatial visualization ability and reading ability, are ill-prepared to demonstrate a high level of achievement in technical drawing. The previously unexplored relationship between these three, highly synergistic variables provided the foundation and catalyst for this study. Students' demonstrating these abilities have an established foundation for a successful and rewarding technical career.

This author urges others to study, in detail, the relationships between the universal graphic language and our written and spoken language, as they relate to technical drawing. Spatial visualization ability and reading ability are synonymous terms, and are delineated only by the language which they serve. However, the languages, although seemingly symbiotic, are as synergistic as are these variables.

If technical drawings are the windows through which we see things, as Booker (1979) stated, then we dare not close the blinds on these windows. Rather, we need to regularly open and clean the windows through which the future is seen. Humankind thinks in terms of the languages it knows. The universal graphic language is a way of thinking. One who can draw, can think of and deal with many things and problems which another cannot. The person who is looking through the "picture windows" of technical drawing is looking toward the images that preceded the words, as Hubbard (1988) described.

A student's ability to read, to write, and to speak words and their spatial visualization ability are combined synergistically in the learning and application of the universal graphic language. The student thinks in terms of the languages he or she knows. It may be said, that the better known the languages, the better the thinking becomes. This study was based upon its author's initial observations and subsequent hypothesis that these previously unexplored relationships were both significant and worthy of research. Reading comprehension is to reading what spatial visualization is to technical drawing. These abilities are optimally integrated in technical drawing. The synergistic relationship which exists between these variables demands further research.

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APPENDICES

APPENDIX A

REVISED MINNESOTA PAPER FORM BOARD TEST

Revised Minnesota Paper Form Board Test

The Revised Minnesota Paper Form Board Test (RMPFBT) is an aptitude or ability test which assesses a student's spatial visualization ability or capacity to visualize geometric shapes. The RMPFBT is a 20 minute timed test that takes advantage of both speed and power. Speed tests are composed of relatively easy items and rely on restrictive time limits to differentiate among examinees, while power tests rely on item difficulty to discriminate between examinees.

The RMPFBT Series AA examination which was administered to the cluster sample, consisted of 64 two-dimensional, geometric shaped diagrams depicted as cut into separate pieces. The diagrams increase in difficulty toward the end of the test. For each of the 64 diagrams, there are five figures with lines indicating the different shapes out of which they are made. From these five choices, the examinee must accurately visualize the separate pieces as a whole geometric shape. He or she then chooses the one figure that is composed of the exact parts that are shown in the original diagram. The students were given 20 minutes to complete the RMPFBT Series AA test.

Table 4 presents the RMPFBT raw score and normed percentile (%) ranking summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores and normed percentile (%) rankings of the sample consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 4

Revised Minnesota Paper Form Board Test Raw Score and Normed Percentile Ranking Summary

Student	Raw Score	Normed Percentile (%) Ranking
S1	41	50
S2	52	90
S3	40	50
S4	52	90
S5	48	80
S6	32	20
S7	42	55
S8	38	40
S9	47	75
S10	59	99
S11	63	99
S12	55	95
S13	39	45
S14	40	50
S15	40	50
S16	51	85
S17	48	80
S18	47	75
S19	54	95
S20	58	97
S21	42	55
S22	49	80
S23	54	95
S24	55	95

(table continues)

Student	Raw Score	Normed Percentile (%) Ranking
S25	52	90
S26	46	70
S27	53	90
S28	49	80
S29	43	60
S30	35	30
S31	47	75
S32	42	55
S33	45	70
S34	55	95
S35	47	75
S36	42	55
S37	49	80
S38	43	60

Note. $N_{sample} = 38$

$M_{raw} = 47.2$ $SD_{raw} = 6.9$

$M_{normed} = 71.8$ $SD_{normed} = 20.9$

Table 5 presents the RMPFBT raw score summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores of the sample and the normed group consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 5

Revised Minnesota Paper Form Board Test Raw Score Summary

Student	Correct	Incorrect	Omitted	Raw Score
S1	42	5	17	41
S2	54	10	0	52
S3	40	1	23	40
S4	54	10	0	52
S5	48	0	16	48
S6	34	11	19	32
S7	46	18	0	42
S8	42	22	0	38
S9	47	2	15	47
S10	60	4	0	59
S11	63	1	0	63
S12	56	4	4	55
S13	42	17	5	39
S14	40	2	22	40
S15	42	11	11	40
S16	52	4	8	51
S17	48	0	16	48
S18	49	10	5	47
S19	54	2	8	54
S20	58	2	4	58

(table continues)

Student	Correct	Incorrect	Omitted	Raw Score
S21	44	10	10	42
S22	49	2	13	49
S23	54	1	9	54
S24	56	6	2	55
S25	54	10	0	52
S26	48	8	8	46
S27	54	4	6	53
S28	49	1	14	49
S29	45	11	8	43
S30	38	15	11	35
S31	50	14	0	47
S32	46	18	0	42
S33	47	11	6	45
S34	56	4	4	55
S35	50	14	0	47
S36	44	8	12	42
S37	49	0	15	49
S38	45	8	11	43

Note. $N_{sample} = 38$

$M_{sample\ raw} = 47.21$ $SD_{sample\ raw} = 6.94$

$N_{normed\ group} = 544$

$M_{normed\ group\ raw} = 40.10$ $SD_{normed\ group\ raw} = 10.20$

Table 6 delineates the 23 RMPFBT normed data percentile (%) ranking values, including their associated raw scores. The sample size (N) from which the normed scores were derived is provided, as are the normed sample mean value (M) and standard deviation (SD). Each raw score presented in Table 4 was converted to one of the 23 designated percentile values as found in Table 6.

Each percentile value represents the midpoint of a zone, or band, of ability. In most cases, the zones are five percentile units wide. However, the zones differ at the extremes; a percentile rank of 5 includes percentile ranks 4 through 7; a percentile rank of 3 includes 2 and 3; and a rank of 1 includes the first percentile only. Similarly, the 95th percentile includes ranks of 93 through 96; 97 includes 97 and 98; and 99 includes only the 99th percentile. The normed raw scores and percentile values data represents a national sample as published by The Psychological Corporation in the second edition of the Revised Minnesota Paper Form Board Test Manual (Likert & Quasha, 1995, p. 62).

Table 6

Revised Minnesota Paper Form Board Test Normed Data Summary

Normed Percentile (%) Value	Raw Score
99	59-64
97	56-58
95	54-55
90	52-53
85	50-51
80	48-49

(table continues)

Normed Percentile (%) Value	Raw Score
75	47
70	45-46
65	44
60	43
55	42
50	40-41
45	39
40	38
35	37
30	35-36
25	33-34
20	30-32
15	28-29
10	25-27
5	20-24
3	15-19
1	0-14

Note. $\underline{N}_{\text{normed group}} = 544$

$\underline{M}_{\text{normed group raw}} = 40.10$ $\underline{SD}_{\text{normed group raw}} = 10.20$

APPENDIX B

TESTS OF ADULT BASIC EDUCATION: READING SUBTEST

Tests of Adult Basic Education: Reading Subtest

The Tests of Adult Basic Education (TABE) reading subtest assesses a student's reading ability in a grade level measurement range from 0.0 through 12.9. The grade level reading (GLR) equivalency score provided in Table 7, indicates the grade and month in school at which an average student would perform about as well as the test taker has performed. The students were given 50 minutes to complete the TABE Form 7, Level A reading subtest.

The TABE reading subtest measures basic reading skills in a variety of contexts. In addition, the test measures vocabulary skills as part of the reading process. The content also includes items which measure both prose and document literacy, as well as measuring the ability to find and use information. The TABE reading subtest consists of 50 items requiring a timed testing period of 50 minutes. The test objectives include measures for the student's interpretation of graphic information (10 items), understanding of words in context (5 items), recall of information (5 items), understanding of construct meanings (15 items), and the evaluation and extension of meaning (15 items).

Table 7 presents the TABE reading subtest raw score and normed percentile (%) ranking summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores and normed percentile (%) rankings of the sample consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 7

Tests of Adult Basic Education: Reading Subtest Raw Score and Normed Percentile Ranking Summary

Student	Raw Score	Normed Percentile (%) Ranking	GLR
S1	32	53	9.2
S2	42	85	12.9 +
S3	44	90	12.9 +
S4	42	85	12.9 +
S5	40	80	12.9 +
S6	43	88	12.9 +
S7	40	80	12.9 +
S8	46	94	12.9 +
S9	45	92	12.9 +
S10	40	80	12.9 +
S11	47	97	12.9 +
S12	41	83	12.9 +
S13	32	53	9.2
S14	45	92	12.9 +
S15	43	88	12.9 +
S16	39	76	12.6
S17	37	70	11.1
S18	37	70	11.1
S19	43	88	12.9 +
S20	48	98	12.9 +
S21	29	42	8.2
S22	44	90	12.9 +
S23	48	98	12.9 +
S24	42	85	12.9 +

(table continues)

Student	Raw Score	Normed Percentile (%) Ranking	GLR
S25	40	80	12.9 +
S26	38	73	11.5
S27	37	70	11.1
S28	40	80	12.9 +
S29	42	85	12.9 +
S30	35	63	10.6
S31	42	85	12.9 +
S32	43	88	12.9 +
S33	35	63	10.6
S34	40	80	12.9 +
S35	41	83	12.9 +
S36	40	80	12.9 +
S37	40	80	12.9 +
S38	41	83	12.9 +

Note. $N_{sample} = 38$

$M_{raw} = 40.6$ $SD_{raw} = 4.3$

$M_{normed} = 80.3$ $SD_{normed} = 12.6$

Table 8 presents the TABE reading subtest raw score summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores of the sample consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 8

Tests of Adult Basic Education: Reading Subtest Raw Score Summary

Student	Correct	Incorrect	Omitted	Raw Score
S1	32	18	0	32
S2	42	8	0	42
S3	44	6	0	44
S4	42	8	0	42
S5	40	10	0	40
S6	43	7	0	43
S7	40	10	0	40
S8	46	4	0	46
S9	45	5	0	45
S10	40	10	0	40
S11	47	3	0	47
S12	41	9	0	41
S13	32	18	0	32
S14	45	5	0	45
S15	43	7	0	43
S16	39	11	0	39
S17	37	10	3	37
S18	37	13	0	37
S19	43	7	0	43
S20	48	2	0	48
S21	29	21	0	29
S22	44	6	0	44
S23	48	2	0	48
S24	42	8	0	42

(table continues)

Student	Correct	Incorrect	Omitted	Raw Score
S25	40	10	0	40
S26	38	12	0	38
S27	37	13	0	37
S28	40	10	0	40
S29	42	8	0	42
S30	35	15	0	35
S31	42	8	0	42
S32	43	7	0	43
S33	35	15	0	35
S34	40	10	0	40
S35	41	9	0	41
S36	40	10	0	40
S37	40	10	0	40
S38	41	9	0	41

Note. $N_{sample} = 38$

$M_{raw} = 40.60$ $SD_{raw} = 4.26$

Table 9 provides a summary of student's individual performance relative to the 5 categorical test objectives of the TABE reading subtest. The individual students are identified as S1 through S38. The objectives included measures for the student's interpretation of graphic information (IGI), understanding of words in context (UWC), recall of information (ROI), understanding of construct meanings (UCM), and the evaluation and extension of meaning (EEM). The number of questions within each category are also provided in Table 9.

Table 9

Tests of Adult Basic Education: Reading Subtest Objective Category Summary

Objective	IGI	UWC	ROI	UCM	EEM
Number of Questions	10	5	5	15	15
Student					
S1	5	4	3	8	12
S2	8	4	4	11	15
S3	9	4	5	13	13
S4	9	4	4	12	13
S5	8	3	3	13	13
S6	9	4	3	13	14
S7	9	3	4	11	13
S8	10	4	5	12	15
S9	10	4	4	13	14
S10	9	4	5	10	12
S11	10	4	4	15	14
S12	10	3	5	12	11
S13	8	4	0	10	10
S14	10	4	5	12	14
S15	9	4	4	14	12
S16	8	3	4	11	13

(table continues)

Objective	IGI	UWC	ROI	UCM	EEM
Number of Questions	10	5	5	15	15
Student					
S17	10	3	3	9	12
S18	8	2	4	11	12
S19	10	4	4	10	15
S20	10	4	5	15	14
S21	7	1	2	12	7
S22	10	3	4	13	14
S23	10	5	5	13	15
S24	10	4	2	13	13
S25	9	5	3	11	12
S26	9	3	2	11	13
S27	7	4	3	10	13
S28	9	2	5	13	11
S29	9	5	4	11	13
S30	9	2	4	9	11
S31	9	3	5	12	13
S32	10	3	3	13	14
S33	10	4	2	9	10
S34	10	5	3	10	12
S35	10	5	4	10	12
S36	9	2	5	13	11

(table continues)

Objective	IGI	UWC	ROI	UCM	EEM
Number of Questions	10	5	5	15	15
Student					
S37	9	4	3	13	11
S38	10	4	4	12	11

Note. $N_{sample} = 38$

$M_{IGI} = 9.08$ $SD_{IGI} = 1.10$

$M_{UWC} = 3.62$ $SD_{UWC} = .95$

$M_{ROI} = 3.71$ $SD_{ROI} = 1.14$

$M_{UCM} = 11.66$ $SD_{UCM} = 1.66$

$M_{EEM} = 12.55$ $SD_{EEM} = 1.66$

Table 10 provides a summary of student's individual mastery level relative to the 5 categorical test objectives of the TABE reading subtest. The individual students are identified as S1 through S38. The objective categories included measures for the student's interpretation of graphic information (IGI), understanding of words in context (UWC), recall of information (ROI), understanding of construct meanings (UCM), and the evaluation and extension of meaning (EEM).

Students demonstrated mastery (Ma), partial mastery (PMa), or nonmastery (NMa) in each of the five categories. Mastery of an objective required that 75% or more of the responses were correct, while partial mastery of an objective required that 50% or more of the responses were correct. Nonmastery required that less than 50% of the category questions were answered correctly.

Table 10

Tests of Adult Basic Education: Reading Subtest Objective Category Mastery Summary

Objective	IGI	UWC	ROI	UCM	EEM
Student					
S1	PMa	Ma	PMa	PMa	Ma
S2	Ma	Ma	Ma	PMa	Ma
S3	Ma	Ma	Ma	Ma	Ma
S4	Ma	Ma	Ma	Ma	Ma
S5	Ma	PMa	PMa	Ma	Ma
S6	Ma	Ma	PMa	Ma	Ma
S7	Ma	PMa	Ma	PMa	Ma
S8	Ma	Ma	Ma	Ma	Ma
S9	Ma	Ma	Ma	Ma	Ma
S10	Ma	Ma	Ma	PMa	Ma
S11	Ma	Ma	Ma	Ma	Ma
S12	Ma	PMa	Ma	Ma	PMa

(table continues)

Objective	IGI	UWC	ROI	UCM	EEM
Student					
S13	Ma	Ma	NMa	PMa	PMa
S14	Ma	Ma	Ma	Ma	Ma
S15	Ma	Ma	Ma	Ma	Ma
S16	Ma	PMa	Ma	PMa	Ma
S17	Ma	PMa	PMa	PMa	Ma
S18	Ma	NMa	Ma	PMa	Ma
S19	Ma	Ma	Ma	PMa	Ma
S20	Ma	Ma	Ma	Ma	Ma
S21	PMa	NMa	NMa	Ma	NMa
S22	Ma	PMa	Ma	Ma	Ma
S23	Ma	Ma	Ma	Ma	Ma
S24	Ma	Ma	NMa	Ma	Ma
S25	Ma	Ma	PMa	PMa	Ma
S26	Ma	PMa	NMa	PMa	Ma
S27	PMa	Ma	PMa	PMa	Ma
S28	Ma	NMa	Ma	Ma	PMa
S29	Ma	Ma	Ma	PMa	Ma
S30	Ma	NMa	Ma	PMa	PMa
S31	Ma	PMa	Ma	Ma	Ma
S32	Ma	PMa	PMa	Ma	Ma
S33	Ma	Ma	NMa	PMa	PMa
S34	Ma	Ma	PMa	PMa	Ma
S35	Ma	Ma	Ma	PMa	Ma
S36	Ma	NMa	Ma	Ma	PMa
S37	Ma	Ma	PMa	Ma	PMa
S38	Ma	Ma	Ma	Ma	PMa

Note. $N_{sample} = 38$

APPENDIX C

NATIONAL OCCUPATIONAL COMPETENCY TESTING INSTITUTE:

JOB READY/STUDENT GENERAL DRAFTING AND DESIGN

WRITTEN ASSESSMENT

National Occupational Competency Testing Institute:

Job Ready/Student General drafting and Design Written Assessment

The National Occupational Competency Testing Institute (NOCTI) Job Ready/Student General Drafting and Design written examination assesses the students' achievement in the field of general drafting and design. The students were given 180 minutes to complete this 173 item written test.

The written assessment consisted of 173 questions covering 8 areas of understanding in general drafting and design. Forty percent of the test questions were related to traditional mechanical drafting. Sixteen percent deal with basic drawing skills. Twelve percent of the questions cover systems drafting. Nine percent of the questions were related to the introduction to drafting, while 8% elicit responses relative to preparing to draw. Architectural drafting and calculations used in drawing were each represented by 6% of the questions in the assessment. Lastly, 3% of the questions were related to drafting with machines.

Table 11 presents the NOCTI Job Ready/Student General Drafting and Design written assessment raw score and normed percentile (%) ranking summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores and normed percentile (%) rankings of the sample consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 11

National Occupational Competency Testing Institute: Job Ready/Student General Drafting and Design Written Assessment Raw Score and Normed Percentile Ranking Summary

Student	Raw Score	Normed Percentile (%) Ranking
S1	80	19.7
S2	72	6.6
S3	138	98.7
S4	85	25.0
S5	85	25.0
S6	79	17.1
S7	117	82.9
S8	95	48.7
S9	125	93.4
S10	107	67.1
S11	97	51.3
S12	78	13.2
S13	92	36.8
S14	118	86.8
S15	101	57.9
S16	105	61.8
S17	66	3.9
S18	112	77.6
S19	86	30.3
S20	118	86.8
S21	75	9.2
S22	93	42.1
S23	133	96.1
S24	101	57.9

(table continues)

Student	Raw Score	Normed Percentile (%) Ranking
S25	85	25.0
S26	116	80.3
S27	111	75.0
S28	108	69.7
S29	110	72.4
S30	78	13.2
S31	89	32.9
S32	99	53.9
S33	94	46.1
S34	92	36.8
S35	123	90.8
S36	93	42.1
S37	106	64.5
S38	48	1.3

Note. $N_{sample} = 38$

$M_{raw} = 97.6$ $SD_{raw} = 19.2$

$M_{normed} = 50.0$ $SD_{normed} = 29.2$

Table 12 presents the NOCTI Job Ready/Student General Drafting and Design written assessment raw score summary for the cluster sample (N). The individual students are identified as S1 through S38. The descriptive statistics for the raw scores of the sample consist of the mean value (M) and the standard deviation (SD) which are given following the last student data entry for the sample.

Table 12

National Occupational Competency Testing Institute: Job Ready/Student General Drafting and Design Written Assessment Raw Score Summary

Student	Correct	Incorrect	Omitted	Raw Score
S1	80	93	0	80
S2	72	101	0	72
S3	138	35	0	138
S4	85	88	0	85
S5	85	88	0	85
S6	79	94	0	79
S7	117	56	0	117
S8	95	78	0	95
S9	125	48	0	125
S10	107	66	0	107
S11	97	76	0	97
S12	78	95	0	78
S13	92	81	0	92
S14	118	55	0	118
S15	101	72	0	101
S16	105	68	0	105
S17	66	107	0	66
S18	112	61	0	112
S19	86	87	0	86
S20	118	55	0	118
S21	75	98	0	75
S22	93	80	0	93
S23	133	40	0	133
S24	101	72	0	101

(table continues)

Student	Correct	Incorrect	Omitted	Raw Score
S25	85	88	0	85
S26	116	57	0	116
S27	111	62	0	111
S28	108	65	0	108
S29	110	63	0	110
S30	78	95	0	78
S31	89	84	0	89
S32	99	74	0	99
S33	94	79	0	94
S34	92	81	0	92
S35	123	50	0	123
S36	93	80	0	93
S37	106	67	0	106
S38	48	125	0	48

Note. $N_{sample} = 38$

$M_{sample\ raw} = 97.63$ $SD_{sample\ raw} = 19.15$

$N_{normed\ group} = 472$

$M_{normed\ group\ raw} = 101.00$ $SD_{normed\ group\ raw} = 25.63$

Table 13 provides a summary of student's individual performance relative to the 8 categorical objectives of the NOCTI Job Ready/Student General Drafting and Design written assessment. The individual students are identified as S1 through S38. The objectives included measures of performance for preparing to draw (PTD), basic drawing skills (BDS), introduction to drafting (ITD), architectural drafting (ARD), systems drafting (SYD), drafting with machines (DWM), calculations used in drawing (CUD), and mechanical drafting (MED). The number of questions within each category are provided in Table 13.

Table 13

National Occupational Competency Testing Institute: Job Ready/Student General Drafting and Design Written Assessment Objective Category Summary

Category	PTD	BDS	ITD	ARD	SYD	DWM	CUD	MED
Number of Questions	13	28	16	10	20	5	11	70
Student								
S1	8	18	8	7	7	4	6	22
S2	9	15	13	5	4	4	2	20
S3	12	21	16	10	17	5	9	48
S4	8	18	6	10	6	1	4	32
S5	12	22	7	7	5	2	5	25
S6	9	21	9	3	6	4	3	24
S7	12	22	12	9	11	3	7	41
S8	9	19	6	9	9	2	3	38
S9	12	22	14	10	15	4	9	40
S10	9	20	11	8	7	4	5	43
S11	9	20	10	7	12	3	2	34
S12	5	19	7	7	6	3	3	28

(table continues)

Category	PTD	BDS	ITD	ARD	SYD	DWM	CUD	MED
Number of Questions	13	28	16	10	20	5	11	70
Student								
S13	8	19	9	8	8	5	6	29
S14	10	19	12	8	13	5	6	45
S15	10	20	8	7	11	3	6	36
S16	11	21	13	5	6	3	10	36
S17	7	14	8	8	5	3	1	20
S18	11	22	14	8	13	3	8	33
S19	8	15	7	9	12	3	1	31
S20	11	18	11	8	12	4	5	49
S21	6	22	6	8	6	3	4	20
S22	11	18	11	7	8	3	2	33
S23	12	22	13	9	13	4	8	52
S24	12	23	10	9	10	5	5	27
S25	10	18	7	8	9	3	7	23
S26	11	24	11	9	13	3	2	43
S27	10	19	13	9	9	4	4	43
S28	13	21	11	8	6	4	6	39
S29	10	20	13	2	5	5	7	48
S30	12	14	9	5	5	3	2	28
S31	7	21	11	9	6	4	2	30
S32	12	17	9	4	11	5	9	32
S33	9	19	10	6	8	3	4	35
S34	10	20	7	2	9	3	5	36
S35	12	23	15	8	9	4	7	45
S36	9	18	10	5	7	4	3	37

(table continues)

Category	PTD	BDS	ITD	ARD	SYD	DWM	CUD	MED
Number of Questions	13	28	16	10	20	5	11	70
Student								
S37	8	19	15	5	7	5	8	39
S38	4	4	2	6	6	1	4	21

Note. $N_{sample} = 38$

$M_{PTD} = 9.68$ $SD_{PTD} = 2.13$

$M_{BDS} = 19.13$ $SD_{BDS} = 3.50$

$M_{ITD} = 10.10$ $SD_{ITD} = 3.07$

$M_{ARD} = 7.16$ $SD_{ARD} = 2.11$

$M_{SYD} = 8.74$ $SD_{SYD} = 3.21$

$M_{DWM} = 3.53$ $SD_{DWM} = 1.03$

$M_{CUD} = 5.00$ $SD_{CUD} = 2.48$

$M_{MED} = 34.34$ $SD_{MED} = 8.97$