Computer Programming:
Science, Art, or Both?

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Introduction

Brief History of Computers

The oldest artificial computing device is the ancient abacus. The next to appear on the scene were the Arithmetic Machine built by Blaise Pascal around 1643 and the Four Function Calculator of Gottfried Wilhelm von Leibnitz around 1663. None of these devices required a computer program (Mayer, 1988).

From 1710 to 1750, Bouchon, Falcon, and Jacques developed paper tape and punched cards. Around 1800, Joseph Jacquard perfected storing information on continuous paper cards which held complex, digitized instructions of intricate patterns for weaving looms (Masters, 1994).

Around 1810, Charles Babbage started building his Difference Engine, which he did not complete since he found a more efficient way of computing data mechanically. This new way resulted in the Analytical Engine in 1835, which he also did not complete because he had discovered yet a more efficient way of computing data mechanically (Masters, 1994).

Around 1900, Herman Hollerith founded the Tabulating Machine Company. His mechanical tabulators were used for counting and sorting punched cards by the U.S. Census Bureau (Mayer, 1988). In 1940, John Atanasoff at Iowa State University completed the first functional electronic digital computer. In 1944, Howard Aiken at Harvard University completed the Mark-I, an electromechanical calculator, which was very slow. In 1946, J. Presper Eckert and John W. Mauchly completed ENIAC (Electronic Numerical Integrator and Calculator), a monstrous machine containing 18,000 vacuum tubes. This computer had no stored program; program changes were made by changing the hard wiring. Until 1955, this machine was used by the U.S. Army Ballistic Research Labs (Mayer, 1988).

In 1952, John von Neumann built the first computer which used a flexible stored program. Modern computers have enough in common with this machine that they are said to have a von Neumann architecture (Sethi, 1989).

Late in the 1960s, the integrated circuit was introduced. This circuit resulted in a reduction in price, size, and failure rate. In the mid 1970s, the LSI (large scale integrated circuit) was introduced; this was followed by the VLSI (very large scale integrated circuit) (Masters, 1994). These advances ushered in the computers of today.

Brief History of Programming Languages

The first computer language was machine language, the language executed by the computer. Machine language was originally referred to as code; today, code refers to many other languages (Sethi, 1989). Since machine language consists of only on or off switches, it is represented by 0s and 1s. Programming in machine language is tedious and error prone. Machine language was followed by assembly language. Assembly languages are more advanced than machine languages as they permit the use of mnemonics instead of the 0s and 1s of machine language (Zak, 1995). For example, the machine language instruction 101110110000000000001010 (BB000A hex) is required to put the number 10 into the BX register on the typical personal computer; in assembly language this instruction is MOV BX, 10. An assembler converts assembly code into machine code (Zak).

The next advance in computer languages was the advent of high-level languages which permit the use of instructions resembling the English language. These languages require an interpreter or compiler to translate them into machine code. Most of these high-level languages are procedure oriented which places the emphasis on how to accomplish a task. The next languages were object-oriented languages like Smalltalk and C++ which emphasize the creation and manipulation of objects.

The introduction of GUIs (Graphical User Interfaces) and the Windows type of environments complicated things for the programmers and simplified things for the users.

This could have been the end of the do-it-yourself programmer, but for a new category of high-level languages, the object-oriented / event-driven programming languages which emphasize the included objects and the events that occur on those objects (Zak, 1995). These languages simplify the task of programming for Windows applications and include Visual Basic, Visual C++, and Visual Pascal.

Computers and Education

Presently, computer science departments exist in most colleges and universities. Even most elementary, middle, and high schools offer some type of computer experience(s) to their students. There is wide variation at all levels in the computer science curriculum. Much of this variation is due to the relatively recent appearance of computers in the schools. Many state education departments, including West Virginia, do not recognize computer science as a teaching field. Thus, the teachers in the public schools come from many areas of the curriculum. The result is many different approaches to teaching computer science.

Computers did not appear in large universities until the late 1950s (Rettig, 1994) and were not common until the 1960s. At that time, they generally appeared as part of an engineering, mathematics, or business school in a university. The first computer science department was established at Purdue in 1962. In that same year, Carbato at MIT developed the CTSS time sharing system. In 1964, both the IBM360 and the DEC PDP-8 were produced. The DEC PDP-8 was the first mass-produced mini-computer. The first Ph.D. in computer science was granted to Wexelblat at the University of Pennsylvania in 1968 (Rettig).

The languages used were generally Assembly, FORTRAN, or COBOL, and programs were generated on punched cards at a keypunch machine. The student then carried the deck of cards to an operator. The operator sent the cards through a card reader, and, in an hour or two on a good day, the student would receive a printout of his / her program with the output, the desired outcome assuming the output was correct. Alternatives were the wrong output which often required many hours of following the code, step by step, with paper and pencil or the printout and a list of syntax errors; either result required a return trip to the key punch room and one or more repetitions of the scenario. User-friendly was a term that had not yet come into existence (Milenkovic, 1987).

Although some of the leading universities developed computer science departments in the 1960s, it was the early to mid 1970s before computer science departments became stand-alone departments in many other colleges and universities. As these departments appeared, there was very little standardization in the curriculum. In 1978, the ACM (Association of Computing Machinery) published guidelines for computer science curricula (Kruse, 1984). These guidelines were the first to become widely used as a model for undergraduate computer science education (Rettig, 1994). In 1984, the ACM published a new set of guidelines which encouraged the emphasis of software engineering principles; another update was published in 1991. The major theme in this update was that introductory computer science courses should include an introduction to various areas of computer science (Nyhoff and Leestma, 1992). Thus, computer science is a new field in universities, colleges, and schools. Not only is it young, but the changes in hardware and software, occurring at a very rapid rate, tend to keep it unsettled.

The Eight Intelligences

In 1983 Gardner suggested seven distinct intelligences which make up the core of each individual's ability to perform various tasks at varying degrees of competence. These intelligences are linguistic, mathematical-logical, spatial, bodily kinesthetic, musical, interpersonal, and intrapersonal. In 1995 Gardner added an eighth intelligence which he called the naturalist (Bellanca, Chapman, and Swartz, 1994)[1]. Mathematical-logical and linguistic intelligences are the ones most valued in the school systems of the

[1]Bellanca, Chapman, & Swartz (1994) is in a second edition. This edition added a chapter on the naturalist intelligence.

United States at the present time (Gardner, 1983). When it comes to standardized testing, mathematical-logical intelligence is given the most attention by schools in the United States (Chapman, 1993).

Since its inception, computer programming has been associated with mathematical-logical intelligence. On the other hand, engineering is often associated with spatial intelligence. When the ACM advocated the teaching of computer science by application of software engineering principles, it would seem that computer programming would have become associated with engineering rather than with mathematics. However, this has not been the case.

> After reading the problem specifications and after the requisite amount of procrastination, most novice programmers simply begin to write code. Obviously, their goal is to get their programs to execute, preferably with correct results. Therefore, they run their programs, examine error messages, insert semicolons, change the logic, delete semicolons, pray, and otherwise torture their programs until they work. Most of their time is probably spent checking both syntax and program logic. (Carrona, 1995, p.3)

Although this quote illustrates the trial and error method applied by beginning programmers, it will not work with the software and the programs of today. The programs are large, require teams of programmers, and require application of engineering principles.

Purpose of the Study

The purpose of this study was to investigate if only the mathematical-logical intelligence is required for a successful computer programmer or if spatial intelligence contributes equally or to some extent to the successful computer programmer. Secondary purposes were to determine students' perceptions of their intelligences and if they were related to test performance.

Significance of the Problem

Computers were not available to the average person until the late 1970s and not a common household appliance until the late 1980s. Computers are relatively new in education, and the computer science major is a relatively new major in colleges and universities. Few studies applying to computer science majors have been done. It was not until 1984, that the ACM advocated the application of software engineering methodology to the teaching of computer programming. Traditionally, computer programming has been associated with the mathematical-logical intelligence, although as early as 1974, Yohoe had made a statement similar to, "Computer programming is an art as well as a science."

Limitations

The study was performed with a small group of students at a small university. All students are accepted into the major during their freshmen year. However, all of these students may not be successful in computer science. Some may drop out because they do not like the field, and some may drop out because they cannot do the advanced work.

Chapter 2

Review of the Literature

Introduction

Consider two 11-year-old children taking a standardized test of intelligence. One performs at a superior level, and the other only at an average level. Teachers look at the scores and begin to expect the child performing at a superior level on the test to perform at a superior level in school but expect only moderate success for the child whose score was average. Consequently, the child who scored high on the "intelligence" test does do well in school while the other remains only "average" in school. The predictions, based on test scores, of the teachers do come true. After completion of school, one may find the "average" child as a successful engineer, highly respected in both his career and his community. The other may have achieved only "average" success (Gardner, 1993). How does this happen? This example is based on the facts of intelligence testing which accurately predict success in school, but are a mediocre predictor of performance in a profession after formal schooling (Jencks, 1972). Many students who can solve a category of problems presented in schools do not understand the concepts well enough to apply them in a different situation (Gardner, 1991).

In 1983, Gardner published Frames of Mind in which he advocated that, instead of the notion of intelligence that is measured by standardized tests, there are at least seven intelligences. Of these seven, the standardized test measures only mathematical-logical and linguistic intelligence, but fails to measure spatial, bodily kinesthetic, musical, interpersonal, and intrapersonal intelligence. "Placing logic and language on a pedestal reflects the values of our Western culture and the great premium placed on the familiar tests of intelligence" (Gardner, p. 35). When applying educational standards, two errors may occur. The first is when the goal is the perfect test score and the second is when the student is treated as a product (Bellanca et al., 1994). When students can be thought of as diversely intelligent rather than being measured against one fixed standard with outdated instruments, true change in performance will occur (Chapman, 1993).

In recent years, the term "critical thinking" has received much attention, and courses in critical thinking have been conducted. However, it is very possible that each intelligence exhibits its own particular type of critical thinking or logic and that it must be taught and/or learned as a part of that domain. Consider the thinking required in debugging a computer program, or that required in literary criticism, or that required in choreographing a new dance; are they not different? Would having the critical thinking skills to debug a program transfer to choreographing a dance or to being a literary critic (Gardner, 1993)?

Neither are learning styles consistent across intelligences in each individual. Consequently, Gardner (1993) states that both styles and content need to be charted in order to determine which styles seem to be related to specific content and which may operate across most bodies of content. Even this might need to be done on an individual basis.

Brain research is progressing more rapidly. With this progression, many of the intelligences are being shown to reside in particular physical locations in the brain. What multiple intelligence theory lacks is strong experimental tests within psychology (Gardner, 1993), although it is being tested in many educational projects. Many talents, possibly intelligences, are being overlooked; unfortunately, the individuals with these talents are the chief casualties of this single-minded approach to the mind. Our world has many problems and solving them will require application of many intelligences in many ways.

Human cognitive competence should be viewed as an emerging capacity that is likely to be manifest at the intersection of the "individual," a "domain of knowledge," and a surrounding "field." The individual contributes his or her own skills, knowledge, and aims to this intersection. A knowledge domain is needed to arouse these skills. The surrounding "field" consists of a set of institutions which judges when a particular performance is acceptable and when it is unacceptable (Csikszentmihalyi, 1988; Csikszentmihalyi and Robinson, 1986; Gardner, 1993; Gardner and Wolf, 1988).

"It is of paramount importance to assess the particular combination of skills that may earmark an individual for a certain vocational or avocational niche" (Gardner, 1993, p. 27). It is important to consider each individual as possessing a collection of intelligences, and it may, in reality, mean that the sum is greater than the parts when application of intelligence(s) to a domain is considered.

Computer programming differs from both mathematics and what has been traditionally called hands-on classes, including art or some of the traditional technology courses. In many ways, it is a hands-on class as students must be able to perform on the computer; in other ways, it is similar to a mathematics class where students solve problems.

Since its infancy, computer programming has been associated with mathematics. Consequently, mathematical-logical intelligence has been linked to computer programming although little research has been done to discern which intelligences are required in computer programming. Great teachers of computer programming have made remarks similar to, "Computer programming is an art as well as a science" (Wirth, 1986; Yohoe, 1974). If computer programming is an art, spatial intelligence may also be needed by the successful computer programmer. One purpose of this research is to examine whether spatial intelligence is exhibited by the successful computer science student.

The Human Brain

Many analogies have been drawn between the human brain and a computer. The computer takes information from the environment and stores it in buffers until the central processing unit needs it; then it processes it with respect to existing information. This information is then discarded or stored in some permanent form. Similarly, the brain inputs information from the environment through the sensory receptors (visual, auditory, taste, touch, and smell) where it is stored in the sensory registers, much like the input buffers of a computer. This information is retained in the sensory registers briefly and is lost if perception and attention are not used to retain the information (Nelson, 1988).

The brain is a complex organ just as a computer is a complex system. A computer system can be studied from three perspectives. The top level is the software. The designer of the software, the programmer, has to understand the computer at this level. Before a computer is programmed at the top-level, it has to be designed at an intermediate level which involves the logic circuitry. To understand a computer at this level, one must understand logic circuitry and computer hardware. The lowest level of computer knowledge involves the solid-state physics of semi-conductors and component transistors (Sylwester, 1995). After the top-level design of a computer has been completed, many people can interact with it although they do not have to understand it at any of the three design levels.

In a similar way, the brain is studied with either a top-down approach or a bottom-up approach. In the bottom-up approach, small units, involving individual cells or systems of cells, are studied. The top-down approach has been studied longer than the bottom-up approach and involves the study of more complex units of the brain. It is used to study functions and / or behaviors such as movement and language. The top down approach is used by cognitive psychologists, philosophers, and educational researchers (Sylwester, 1995). Our brains, like a computer system, do not have to be understood at either of these levels in order to be used. Unlike a computer, a new brain cannot be purchased. Therefore, a brain must be more adaptable, or it could not function for as many years as some brains function.

A human has about 10^5 genes and approximately 10^{15} (10 trillion) synapses in the brain (Damasio, 1994). The genes determine the brain's main circuits, but the environment shapes the trillions of finer connections (Begley, 1996). Although many structural specifics of the brain are determined by genes, many others are determined by the activity of the human, as he / she develops and continuously changes throughout his / her life span. Genes provide for one brain component with precise structure and for another component in which the precise structure is to-be-determined. The to be determined structure is attained by the influence of the precise structure, the individual activity and circumstances, and self-organizing pressures (Damasio). An experiment with kittens showed that when one eye was sewn shut at birth, so few neurons connected to the visual cortex that the kittens remained blind even after the eye was opened. When older cats had an eye sewn shut, this did not occur (Hubel and Wiesel, 1979). Experience shapes the design of the circuits. Synaptic strengths change throughout the life span as they reflect different experiences; thus, the design of brain circuits continues to change. The circuits are not only sensitive to the results of first experience, but they are modified by continued experiences (Damasio).

The aging brain does not lose its powers as many believe. Older people often have skills and abilities that exceed those of young people. Aging brains have larger vocabularies, a greater understanding of written materials, more ability to reason, and better judgment based on wide experiences (Henry, 1996). There is a direct correlation between the amount of branching in the brain and the level of education; it has not been determined if the brain with more branching desires more education or if more education produces more branching in the brain. The brain may use different areas as it ages, and approximately 30% of its ability to age successfully depends on genetics (Crowley, 1996).

Much of the power of the brain is inherited from many prior generations. In the not too distant past, the main purpose of the brain was to aid in protecting the individual from harm and in meeting his / her daily physical needs. The last 60 years have witnessed dramatic changes when compared with the previously gradual changes. Thus, the brain may not have been given the opportunity to evolve as it had in prior generations

(Sylwester, 1995). Since much of the power of the brain is inherited, the analogy of brain and computer seems less reasonable. Brain theorists now view the brain as an ecological system similar to a large jungle. The brain is a dense web with many connections. In an ecological system, everything that has ever occurred leaves a trace; can our brain environment have a trace of everything that has ever happened to us, to our ancestors? Ecological systems have evolved over time and cannot be changed quickly; neither can the brain (Sylwester). Recent research has shown that memories evoked by odors feel more visual and emotional than those brought on by sight, sound, or taste. In evolution, smell is the most primitive of the senses as man depended on smell to warn of dangers (Crenson, 1996).

As knowledge of the brain has increased, theories on intelligence have changed. It is now accepted that one side of the brain is clearly dominant and that this dominance determines whether an individual is right or left-handed. It has also been established that the left hemisphere is dominant for language in most normal right-handed individuals, while the right-hemisphere is dominant, although not to the same extent, for visual-spatial functions (Gardner, 1983). In more than 95% of all people, including left-handers, language depends on the left hemisphere (Damasio, 1994). This new knowledge allows specificity of cognitive function to be tied to finer regions of the human cerebral cortex (Gardner).

The Eight Intelligences

Gardner (1983) states that a prerequisite for identifying a human intelligence is that the intelligence must be genuinely useful and important in certain cultural situations. He believes there are eight signs, described below, of an intelligence.

The first is demonstrated by individuals who have suffered brain damage. If a particular faculty can be destroyed or spared in isolation as a result of brain damage, its relative autonomy from other faculties seems likely (Chapman, 1993; Gardner, 1983).

The second is the existence of idiots savants, prodigies, and other exceptional individuals. These individuals exhibit a highly uneven profile of abilities and deficits which seem to allow observation of a human intelligence in relative isolation (Chapman, 1993; Gardner, 1983).

The existence of one or more basic information-processing or core operations which can deal with specific kinds of input which spark a particular intelligence is the third sign. Examples include sensitivity to pitch relations as a core for musical intelligence or the ability to imitate movement by others as one core of bodily intelligence. It is crucial to be able to identify these core operations and prove that they are separate (Chapman, 1993; Gardner, 1983).

An intelligence should have an identifiable developmental history through which normal as well as gifted individuals pass. This history implies that it should be possible to identify levels of expertise, ranging from beginning to exceedingly high levels of competency; only those individuals with unusual talent may develop the highest levels of expertise. This identification of the history of the intelligence and analysis of its susceptibility to modification and training is the fourth sign (Chapman, 1993; Gardner, 1983).

Since all species display areas of intelligence and ignorance, a specific intelligence becomes more plausible if one can locate its evolutionary antecedents, including capacities that are shared with other organisms. Location of this fifth sign is an area where speculation is tempting and firm facts are elusive (Chapman, 1993; Gardner, 1983).

There should exist some support from experimental psychology which illuminates the operation of candidate intelligences. For example, the ability to solve a jigsaw puzzle can illuminate visual / spatial intelligence. Using methods of cognitive psychology, the relative autonomy of an intelligence can be investigated. In this sixth area, experimental psychology can help demonstrate the ways in which modular or domain-specific abilities may interact in the execution of complex tasks (Chapman, 1993; Gardner, 1983).

Some intelligences lend themselves to support from psychometric findings. To the extent that the tasks, for example those found in IQ tests, assess one intelligence and correlate highly with another and less highly with those that assess other intelligences, an intelligence may be supported. With the seventh sign, it must be noted that intelligence tests do not always test what they claim and that many rely too heavily on pencil-and-paper methods to test some intelligences (Chapman, 1993; Gardner, 1983).

Finally, an intelligence should have a susceptibility to being encoded in a symbol system. These symbol systems are culturally contrived and capture important forms of information. A primary characteristic of human intelligence may well be its "natural" gravitation toward embodiment in a symbolic system (Chapman, 1993; Gardner, 1983).

An intelligence is not equivalent to a sensory system, but should be capable of being realized through more than one sensory system (Gardner, 1983). When we see, hear, touch, taste, or smell, both body and brain participate. The body contributes a content that is part of the workings of the normal mind (Damasio, 1994). Although an intelligence is more easily observed when it is being used to carry out some action, the possession of an intelligence should be thought of as a potential, used or unused. The question of how specific intelligences come to be linked to carry out more complex tasks is one of utmost importance. It is important to note that Gardner states that the intelligences "exist not as physically verifiable entities but only as potentially useful scientific constructs" (p. 70).

Multiple intelligence theory is not a "type theory" to determine one intelligence in an individual but is a theory of cognitive functioning. Furthermore, it suggests that each individual has ability in all eight intelligences and that the intellect functions not only together but also uniquely, in each individual. Most individuals have some highly developed intelligences, some modestly developed intelligences, and some relatively undeveloped intelligences (Armstrong, 1994).

Gardner (1983) identifies the intelligences as linguistic, musical, mathematical-logical, spatial, bodily kinesthetic, and the personal; the personal intelligences involve both intrapersonal, a "sense of self," and interpersonal, a "sense of others." These seven intelligences are tentative; some may be shown not to exist by Gardner's eight tests. In the same manner, other "new" intelligences may meet the tests (Armstrong, 1994). In 1995, Gardner identified the naturalist intelligence as an eighth intelligence (Bellanca et al., 1994)[2]. Other suggested intelligences include spirituality, sexuality, humor, creativity, and intuition to name only a few (Armstrong).

Linguistic intelligence is the most widely shared and used intelligence among the human species. There are four aspects of linguistic knowledge that are important. The first is the ability to use language to convince others of a course of action, the rhetorical aspect. The second is the mnemonic aspect, the ability to use language to aid in remembering information. The third aspect is the role of language in explanation. This aspect makes language essential for at least the mathematical-logical intelligence which uses the written word for explanation. The last aspect is use of language to explain or reflect upon itself (Gardner, 1983).

By the age of six months, infants in English-speaking homes have different auditory maps than those in Swedish-speaking homes. This is attributed to the different sounds that babies hear. By one year, infants have lost the ability to discriminate sounds that are not significant in their language. The more words that a child hears by the age of two, the larger his / her vocabulary will be. The window on learning language is open from

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[2]Bellanca et al., 1994 is in a second edition. This edition added a chapter on the naturalist intelligence.

birth to approximately 10 years old. Few people past the age of 10 will be able to learn and speak a second language like a native speaker (Begley, 1996).

Basic linguistic intelligence is exhibited by simple sentences and basic communication skills. The complex tasks are expanded vocabulary; humor, exhibited by telling and understanding jokes; and communicating both formally and informally. Higher-order linguistic skills are creative writing, story telling, and appropriate communication in a variety of situations (Chapman, 1993).

The ability to process linguistic messages seems to depend upon an intact left temporal lobe; injuries to or abnormal development of this neural zone generally produce language impairments. These people are generally quite normal at solving other problems if the oral-aural channels can be bypassed. In normal right-handed individuals, language is tied to the operation of areas in the left hemisphere of the brain. However, if the left hemisphere of the brain has been removed during the first year of life, language develops in the right hemisphere. The structure of the development and the use of language seems to be different in different hemispheres of the brain. Since aphasic patients have lost their abilities to be authors while others have been able to retain their abilities to be musicians, visual artists, or engineers, this sparing of occupational skills would be impossible if language were melded into other forms of intellect (Gardner, 1983).

Musical talent emerges in early life. Igor Stravinsky described composing, "..composing is doing, not thinking. It occurs not by acts of thought or will: it is accomplished naturally" (Gardner, 1983, p.103). Researchers at the University of Konstanz, Germany, examined the brains of nine string players and found that the amount of somatosensory cortex dedicated to the thumb and fifth finger of the left hand was significantly larger than in non-players. Although the amount of daily practice did not affect the cortical map, the age at which one started playing did. The younger the child when he / she started playing, the more cortex devoted to playing (Begley, 1996).

The window for learning music is generally between the ages of three and 10; thus, it is much more difficult to learn an instrument as an adult (Begley, 1996). By school age, most children in our culture have a schema of what a song should be like, and, in the majority, there is little further musical development after the school years begin (Gardner, 1983).

The mechanisms by which pitch is apprehended and stored are different from those that process other sounds, especially language. In most tests with normal individuals, musical abilities are lateralized to the right hemisphere; this region may assume for music the same centrality as the left temporal lobe assumes for language (Gardner, 1983).

The core set of musical elements is pitch, rhythm, tone, and the awareness of sound in one's environment. The basic skills of musical intelligence are rhythm recognition and reproduction and sound association. The complex skills are rhythm production and enjoyment of different types of music. The higher-order skills are teaching music to others and the ability to grasp the meanings of musical skills (Chapman, 1993).

Bodily kinesthetic intelligence enables an individual to control and interpret body motion, to manipulate physical objects, and to establish harmony between the mind and the body (Chapman, 1993). Although bodily kinesthetic intelligence has been important in the history of the species for thousands of years, in recent western culture, the activities of reasoning and the activities of the physical part of our nature are considered as two separate activities (Gardner, 1983). As witnessed by the phrase "dumb jock" often heard in university hallways, our culture has come to consider problem-solving routines carried out by logic, language, or some other symbolic system as superior in the school system. This distinction is not drawn in many other cultures; in western culture, this may be a double standard as a recent poll (Pew Research Center for the People and the Press, 1997) concluded that 80% of Americans could identify popular sports figures while only eight to 20% could identify government figures. Another indicator of this double standard is the salary rates of many professional athletes as compared to professional academicians. Part of what we deem thinking contains the same principles that exist in overtly physical manifestations of skill (Gardner).

"I think therefore I am" suggests that thinking and awareness of thinking are the foundations of being. In the beginning it was being, and only later was it thinking. Yet we still begin with being, and only later do we think. "We are, and then we think, and we think only inasmuch as we are" (Damasio, 1994, p. 248). The preceding quote describes what Damasio believes to be Descartes' Error. In other words, the separation of body and mind does not nor can not occur. The suggestion that reasoning, moral judgment, and the suffering that comes from physical pain or emotional turmoil might exist separately from the body is almost absurd. "Although our reactions to pain and pleasure can be modified by education, they are a prime example of mental phenomena that depend on the activation of innate dispositions" (Damasio, p. 262).

Apraxia, the total or partial loss of the ability to perform coordinated movements or manipulate objects in the absence of motor or sensory impairment, is generally the result of an injury to zones of the left hemisphere which are dominant for motor functions. These apraxias often occur with aphasia, partial or total loss of the ability to articulate ideas or comprehend spoken or written language. There is considerable evidence that apraxia is not a linguistic or symbolic disorder. There are individuals whose linguistic and logical capacities have been destroyed but who can carry out highly skilled motor activities (Gardner, 1983).

Forms of bodily kinesthetic intelligence are illustrated in dance, mime, acting, athletics, and inventions. To achieve fame in any one of these requires many long hours of practice and preparation. Wayne Gretzky commented, "...in my own way I've spent almost as much time studying hockey as a med student puts in studying medicine" (Gardner, 1983, p. 231).

From birth, our existence as human beings affects the way others treat us and in turn the way we treat others. It influences our view of our bodies. To deny that our environment plays some type of role would be foolish. Our innermost feelings and emotions affect our whole existence, but to what extent and in exactly what way are not yet determined by science. Feelings and the emotions from which they originate are just as cognitive as other precepts and are the result of a physiological arrangement that has turned the brain into the body's captive audience (Damasio, 1994). These ideas are related to Gardner's sixth and seventh intelligences, the intrapersonal and the interpersonal.

Intrapersonal intelligence is the ability to form an accurate model of oneself, to use that model to function effectively and to assume responsibility for one's life and learning. The basic development in this intelligence is an expression of a range of body states at various times and the awareness of separate self-identity. The complex skills are asking "why," trying to "make sense" of life, and self-improvement and concern. The higher-order skills are conscious control of emotional states and an emerging personal belief system (Chapman, 1993).

Interpersonal knowledge is the ability to notice and make distinctions among other people. In its primitive form, it is the capacity of the young child to discriminate among and to detect the moods of people around him / her. In more advanced form, it allows an adult to read the intentions and desires of those around him / her and to act upon this knowledge (Gardner, 1983). The developmental path for interpersonal intelligence is parental bonding, imitation of sounds, words, gestures, and facial expressions, establishing meaningful peer relationships, consensus-building skills, and recognition of various "social ideals" (Chapman, 1993).

The personal intelligences are difficult to determine in an alien culture. The patterns of development and breakdown of the personal intelligences vary more than the other intelligences, and they offer many more end-states. Although these two intelligences develop and exist, they do not develop or exist in isolation from each other. For that reason, Gardner (1983), although discriminating between them, chose to discuss them together.

Since humans tend to be social beings, the need to use and develop personal intelligences is required if one is accepted as an equal in society. The pressure to employ the personal intelligences is much greater than that to employ any other intelligence. Gardner (1983) uses the term "sense of self" to refer to the balance struck by every individual in every culture between the promptings of "inner feelings" and the pressures of "other persons."

According to Begley (1996), the basis for the circuits controlling emotion are laid before birth. At birth, the parents or caregivers take over. The brain uses the same circuits to generate an emotion as well as to respond to an emotion. If an emotion is reciprocated, the electrical and chemical signals that produced it are reinforced; if on the other hand, it is unreciprocated, met with indifference, or a clashing response, the circuits become confused and fail to strengthen. Between the ages of 10 and 18 months, cells in the prefrontal cortex hook up the emotional regions. This happens at such an early age, that it is difficult to discern between the effects of nurture and inborn character. However, stress and constant threats can rewire emotional circuits.

Studies of motherless monkeys and institutionalized infants show that the absence of the bond between mother and child signals difficulty for their future. Both have difficulty in rearing offspring and in relating to others. Maternal deprivation does not seem to have an effect on other cognitive capacities in monkeys (Gardner, 1983).

Damage to the prefrontal lobes tends to leave all the intelligences except the personal intelligences intact. Broad-based knowledge and reasoning strategies to operate on that knowledge are required to reach a decision about personal problems in a complex social environment. This knowledge depends on numerous systems located in relatively separate brain regions, and emotion and feeling are part of this neural machinery (Damasio, 1994).

In light of the previous discussion, the omission of emotions and feelings from an overall concept of mind does not make sense. However, respectable scientific accounts of cognition do precisely that by omitting emotions and feelings in their treatment of cognitive systems. Feelings are both as cognitive as any other perceptual image and as dependent on cerebral-cortex processing as any other image (Damasio, 1994).

The eighth intelligence, identified by Gardner in 1995, is the naturalist. This intelligence involves the ability to categorize and classify. Individuals who can recognize species of plants or animals in their environment and create taxonomies that classify the many different subspecies exhibit the naturalist intelligence. Young children who can pick out different types of flowers, name different animals, and arrange items such as shoes, cars, and clothes into common categories are using the naturalist intelligence. This intelligence is obvious in the botanist and the zoologist, but must also be developed by the organic chemist, entomologist, the photographer, civil engineer, and those in many areas of medicine (Bellanca et al., 1994).

According to Gardner (1983), Piaget's work applied to the mathematical-logical intelligence. Piaget suggested the basis for mathematical-logical thought is enabled by the handling of objects. The child then progresses from these sensory-motor actions to concrete then to formal operations. However, to Piaget this developmental sequence would apply to all domains of intelligence. Gardner, on the other hand, does not believe that all intelligences follow this fundamental sequence. Furthermore, he believes that there is much more overlap in the steps that Piaget outlined and that boundaries between the steps are not well drawn. This pattern also seems to apply to Western middle-class development and is less relevant in traditional or nonliterate cultures. The circuits for mathematics reside in the brain's cortex, near those for music. These circuits are designed and completed from birth to four years of age (Begley, 1996).

At one time, logic and mathematics were two separate fields. Recently, the two have joined in such a way that logic leads directly to mathematics. Neither the logician nor the mathematician works with objects of every day life; instead both work with abstractions. It is left to the scientist to connect these objects to the real world (Gardner, 1983). The powers of the mathematician rarely extend beyond the boundary of the discipline; he / she loves dealing with abstraction; he / she must be rigorous and skeptical; he / she is sustained by the belief that he / she may be able to create a result that is entirely new, one that will change forever the way others think about mathematical order (Adler, 1972). Possibly, the most central and least replaceable feature of a mathematical gift is the ability to handle long chains of reasoning (Gardner).

Since the time of Aristotle and Plato, western civilization has given primary attention to the development of the mathematical intelligence. Schools in Japan, Germany, and Switzerland emphasize mathematics and science. People in those countries believe that mathematical intelligence can be developed, is the result of disciplined and persistent work, and that parents, students, and teachers are responsible for this development. Studies in the United States show that most people believe that mathematical achievement is due to natural talent (Chapman, 1993).

There are individuals, idiots savants, who, although retarded in most areas, display an ability to calculate very rapidly and accurately. Individuals who can comprehend language and music but who cannot perform even simple mathematical tasks also exist. Some brain damaged people have lost the ability to calculate but not their linguistic ability. Important aspects of numerical ability like understanding of relations and concepts are normally represented in the right hemisphere while the ability to read and produce the signs of mathematics is a left hemisphere function (Gardner, 1983).

Gardner (1983) states that "central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli" (p. 173). Spatial intelligence can involve the ability to produce forms or to manipulate given forms. These abilities are different; thus, an individual may be keen in visual perception but have little ability to draw, imagine, or transform an absent world. However, the fact that practice in one of these areas tends to stimulate development in the others would seem to make spatial skills a separate intelligence. One tends to think of these as visual skills, but spatial intelligence can develop in individuals who are blind and, thus, has no direct connection to the visual world (Gardner). Visual/spatial intelligence involves the ability to see form, color, shape, and texture (Chapman, 1993).

To have spatial intelligence, one must be able to perceive a form or an object and to be able to manipulate this form or object in space. Spatial problems can be phrased verbally, and these verbal problems can be solved strictly in a propositional way. Research suggests that the preferred method of solution to these problems is through visual imagery (Gardner, 1983). Thurstone was one of the first to believe that spatial ability was a separate mental ability. He used factor analysis techniques to isolate seven primary mental abilities. Thurstone described spatial ability as visual skills, spatial manipulation, similarity of visuals, and imagining visuals in other orientations (Jonassen and Grabowski, 1993; Thurstone, 1938, 1940; Thurstone and Thurstone, 1941). Gardner lists these as the ability to recognize instances of the same element, the ability to transform (or to recognize the transformation) of one element into another, the capacity to summon a mental image and to transform that image, and the capacity to produce a graphic likeness of spatial information. Although Gardner gives more detail, both involve imagery and / or transformation of an element or a graphic form.

Damasio (1994) believes that some type of imagery is essential to thought. One must be able to visualize the world in his / her own mind if he / she wants to represent it graphically (Bertoline and Miller, 1990). These images may be visual images, sound images, olfactory images, or words and nonimage abstract symbols, including the symbols used in the mental solution of a mathematical problem. If we could not imagine those symbols, we would not recognize nor could not manipulate them. Benet

Mandelbrot, best known for his work with fractals, physicist Richard Feynman, and Albert Einstein all recognized that they thought in images (Damasio).

Arnheim (1969), like Damasio, believes that thinking clearly about something requires creation of an image of some process or concept. On the other hand, it may be more reasonable that spatial intelligence contributes to thought but is not the basis for all thought. Research on areas of the brain tends to place linguistic ability in the left hemisphere and spatial imagery in the right hemisphere indicating two different types of thought. Individuals, when confronted with a standardized test, appear to use either words or spatial images to solve a problem. Research has shown that most subjects perform best when they can use both linguistic and spatial reasoning while solving a problem (Gardner, 1983).

Piaget believed that spatial intelligence was part of the logical growth of general intelligence and that youth could not deal with the ideas of abstract space and rules governing this space until adolescence. Thus, geometry cannot be appreciated until adolescence (Gardner, 1983). Scientists argue that application of brain research would cause subjects like geometry to be taught at a much earlier age (Hancock, 1996).

Since various research has contributed to classifying spatial intelligence as a right hemisphere function of the brain, it is reasonable that it is a separate intelligence. Spatial intelligence can be found in the group life of many primates. Some individuals exhibit highly developed visual and spatial abilities while only normal abilities in other areas. Spatial competence can be observed in all human cultures. Eskimos have developed a high degree of spatial ability, possibly due to the difficulty in finding their way around their snow-covered environment (Gardner, 1983).

Sex differences are more often observed in tests of spatial intelligence than on most forms of intelligence. This may be because hunting and wandering were mostly a male preoccupation and unsuccessful males faced an early death which contributed to this trait becoming highly evolved. However, Eskimo females are also skilled in spatial intelligence. It is interesting to note that at least 60% of Eskimo children score as high as the top 10% of Caucasian children on tests of spatial ability (Gardner, 1983). Persons ranking in the top 10% in spatial visualization have been identified as possessing a requirement for success in 84 occupations, and 85% of these people are employed as engineers, scientists, drafters, and designers (Bertoline and Miller, 1990). A study on the comparison of a graphics format of data and a tabular format of the same data compared males to females. It concluded that females given the graphics format did not perform as well as males. Also, females given the graphics format did not perform as well as females given the tabular format. This research suggests that tests with an overreliance on graphics presentations will bias the results toward males (Hood and Togo, 1993-94). However, various studies have related spatial visualization to success in mathematics, chemistry, biology. and science; it is also important for language, memory, thinking, learning, and problem solving (Bertoline and Miller).

Mathematical-logical intelligence declines after the third and fourth decades of life and bodily kinesthetic intelligence declines in later life. However, spatial and visual intelligence tend to remain robust, especially in those individuals who have practiced them regularly (Gardner, 1983).

Styles of Learning

Intelligence may be an overworked word in our language. One definition is: "a. The capacity to acquire and apply knowledge. b. The faculty of thought and reason. c. Superior powers of mind" (American Heritage Dictionary, 1994). To each of us, the word conjures up some type of image about some type of intelligence or mental ability. Due to the vagueness and complexity of the word, intelligence, Jonassen and Grabowski (1993) chose to describe it in terms of mental abilities.

Jonassen and Grabowski (1993) base their research on four assumptions:

> Individuals differ in their general skills, aptitudes, and preferences for processing information, constructing

> meaning from it, and applying it to new situations. Individuals also differ in their abilities to perform different school-based or real-world learning tasks and outcomes. These different school-based or real-world learning tasks and outcomes require the use of different skills, aptitudes, and preferences. These general abilities or preferences affect the student's ability to accomplish different learning outcomes; that is, one's learning aptitude interacts with the accomplishment of learning tasks and outcomes. (p. 1)

It would seem that these aptitudes and abilities could be related to the various intelligences described by Gardner (1983). However, multiple intelligence theory is a cognitive model seeking to describe how individuals use their intelligences to solve problems, and this is geared to how the human mind operates on objects such as persons, sounds, and other worldly contents (Armstrong, 1994).

Bloom's Taxonomy of Cognitive Objectives is the best known taxonomy of learning. However, Bloom also helped develop taxonomies of interest, attitudes, values, physical, kinesthetics, and balance. These taxonomies included typing, sports, and mechanics. In the cognitive domain, one begins at the knowledge level, then progresses through the comprehension, application, analysis, synthesis, and finally to the evaluation level (Jonassen and Grabowski, 1993). Chapman (1993) presents a developmental plan for each of the seven intelligences although she uses only the basic, complex, and higher order categories. Another example is the taxonomy of the psychomotor domain, what Gardner would describe as bodily kinesthetic intelligence, presented by Harrow (1972).

In this psychomotor taxonomy, the lowest level is reflex movements such as flexing and stretching. Reflex movements are involuntary in nature and exhibited in all animal life. The second level is basic-fundamental movements, inherent movement patterns that form the basis for specialized complex skilled movements. These movements emerge without formal training and are movements such as walking, running, jumping, and climbing. The third level is perceptual abilities which are characterized by a response, reaction, or decision. Examples are dodging a moving ball, jumping a rope, punting, and catching. The fourth level is physical abilities described as functional characteristics that lead to making skilled movements which require endurance and quick, precise movements. Examples include distance running, weight training, and wrestling. The fifth level is skilled movements. These movements are learned and are reasonably complex skills that result in degrees of efficiency when performing a complex task. Examples are hurdling, catching, batting, and back handsprings. The sixth and last level is nondiscursive communication which consists of forms of movement communication. Nondiscursive communication ranges from facial expressions to dance choreographing. Examples are body posture gesture, efficiently executed movements, and choreographies (Hopkins and Antes, 1990).

Although we have trouble defining intelligence, we know that it plays a crucial role in learning and instruction and is important in the description of individual differences and, as such, is the foundation for many cognitive and personality differences (Jonassen and Grabowski, 1993). In 1938, Thurstone described seven primary mental abilities which represent the component skills of intelligence. He believed that differences in these primary abilities accounted for differences in individual cognitive performances. The abilities that he described were perceptual speed, numerical, word fluency, verbal comprehension, spatial, memory, and inductive reasoning. Guilford's Structure of the Intellect model extended the work of Thurstone and others to identify 180 different mental abilities in its final form. Each of these mental abilities was defined in terms of an operation (five possible) on a specific form of content (four possible) of a specific type of product (six possible) (Jonassen and Grabowski). Both Thurstone and Guilford believed that intelligence involved more than one general ability although neither went as far as Gardner in defining totally different intelligences.

Cognitive controls represent patterns of thinking that control the way individuals process and reason about information, regardless of the type of intelligence or mental ability involved (Jonassen and Grabowski, 1993). Cognitive styles are the typical, self-consistent functional modes demonstrated by individuals in their perceptual and intellectual activities (Witkin, Oltman, Raskin, and Karp, 1971). Abilities allow individuals to perform tasks, and styles control the way the task is performed (Jonassen and Grabowski).

Field dependence / independence has been extensively researched and is also referred to as global-articulated dimension. Field dependence / independence forms a continuous distribution', thus, the terms are relative. In a field-dependent mode, "perception is dominated by the overall organization of the surrounding field, and parts of the field are experienced as 'fused' "(Witkin et al., 1971, p. 4). In a field-independent mode, the parts of the field are perceived as discrete from the field. The field dependence / independence style also exists in persons who are deaf and in persons who are blind from birth (Witkin et al.).

Sex differences have been repeatedly found in the field dependence / independence dimension with boys and men being more field independent than girls and women in both the United States and western European countries as well as in Hong Kong, Japan, Israel, Sierra Leone, Africa, and Nigeria. The evidence to date indicates that sex differences may not be present prior to the age of eight or in the elderly (Witkin et al., 1971). It is interesting to note that these sex differences are similar to those found in spatial reasoning.

There are age-related changes in field dependence / independence also. There appears to be a continuous increase in field independence between the ages of eight and 15; next, there is a leveling off process until sometime after the age of 24; after the age of 24, some studies indicate in the late 30's, there is a continuous decrease in field independence. Thus, most geriatric groups show marked field dependence (Witkin et al., 1971).

Field-independent persons score higher on the Wechsler analytic triad but are not predictably different on either verbal-comprehension or attention-concentration triads. The results were consistent for adults and children on the Wechsler Adult Intelligence Scale and the Wechsler Intelligence Scale for Children. This does not indicate a superior intelligence since the scores vary widely across the two areas which do not correlate (Witkin et al., 1971).

When applying the global-articulated style, those with a global style tend to see the entire field, and its parts are seen only in terms of the whole. Those with global style are also field dependent while those with an articulated style are field independent. Those with an articulated style tend to impose their own order on the field and, thus, see the parts rather than the whole (Jonassen and Grabowski, 1993; Witkin et al., 1971). Persons with a more articulated style show evidence of a developed sense of separate identity while those with a global style tend to rely on external sources for a definition of their attitudes, judgments, sentiments, and views of themselves. Field-dependent, global style, persons are very attentive to and better at remembering faces (Witkin et al.).

The visual / haptic learning style is also continuous with very few individuals residing at either end (Schlenker, 1977). An extremely haptic individual is a normal-sighted person who uses his eyes only when he has to. An extremely visual individual is one who is lost in the dark and depends totally on his visual experiences (Lowenfield, 1945). Visual and haptic perception change with age with individuals becoming more visual as they age. Some researchers have found a relationship between visual / haptic and field dependence / independence while others have not (Jonassen and Grabowski, 1993).

The visualizer / verbalizer learning style deals with a learner's preference to learn with pictures or with words. Visualizers prefer that graphs, diagrams, and pictures be included in text-based material. They use imagery and personalize information. Verbalizers prefer information be presented through words whether they are reading or listening. Many individuals are comfortable with either medium, and research has not shown a vast difference in the two styles (Jonassen and Grabowski, 1993). Some correlation with other areas has been shown to exist in the research. It has been predicted that visualizers are more field dependent and verbalizers are more field independent. One study found that visual style correlated positively with spatial visualization while verbal style correlated with verbal ability. A relationship between right brain dominance and visualizers and left brain dominance and verbalizers has been predicted (Jonassen and Grabowski).

Conceptual style is described as either analytical or relational and deals with forming categories and sorting objects. Individuals who use an analytic style seem to be able to break the background and the foreground apart and see the details of the object rather than the object as a whole. Those who use a relational style tend to categorize objects with a functional style rather than by the details of the objects. Results of research which compared conceptual style and field dependence / independence vary (Jonassen and Grabowski, 1993).

Field dependence / independence seems to be related to several learning styles and possibly to visual and spatial skills. However, there seems to be some inconsistency in the literature. Spatial intelligence seems to remain constant throughout life (Gardner, 1983) while field independence seems to decrease possibly after the age of 30 (Witkin et al., 1971). When applying the visual / haptic style, people become more visual as they age. Verbal style correlates with verbal ability while visual style correlates with visualization. Adult learners are more field independent, and this seems to increase with the amount of formal education (Jonassen and Grabowski, 1993). Adults with more formal education have more branching connections in their brains. However, it is not clear if this is due to the education or if the more active brain desires more education

(Crowley, 1996). Several studies have indicated that males are not only more field independent than females (Witkin et al.), but also have a higher degree of spatial intelligence (Gardner).

Mathematical-Logical and Spatial Intelligence in Computer Programming

In 1974, Yohoe pointed out "programming is an art as in all forms, each individual must develop a style which seems natural and genuine" (p. 225). Even the design and implementation of programming languages from the first version of FORTRAN in the mid 1950s to Ada in the early 1980s have been more art than science as the underlying principles remained vague and accumulation of accepted design alternatives were slow to appear (Pratt, 1984). Although over a thousand different programming languages have been designed, most of these languages have never been used outside the group that designed them while other early languages, once popular, have been replaced by newer languages. However, the differences in individual languages are often due to minor variations in the same principle (Wilson and Clark, 1988).

"Software development is a complex process that is both an art and a science" (Nyhoff and Leestma, 1992, p. 1). The artistic part requires a great deal of imagination, creativity, and ingenuity. It is a science since it uses certain standard techniques and methodologies. Thus, the term software engineering has been applied to the study and use of these techniques. Representation of the world in a graphic form is a basic communication skill used by engineers to change their conceptual designs into sketches or engineering drawings. There is evidence that visualization is very difficult for many students (Bertoline and Miller, 1990).

The view of successful software designers began to change in the 1960s when it was discovered that these designers used a methodology similar to an engineer's approach to problem-solving (Pothering and Naps, 1995). However, it was the 1980s before application of software engineering principles became central in the teaching of computer programming. To many, the word engineering initiates images of elaborate equations with many strange looking symbols and tends to imply problem solving in the mathematical and logical sense. However, this may be a misrepresentation of engineering since in the early stages of a design, the engineer is working with ideas and ignoring most physical construction details (Pothering and Naps). Armstrong (1994) differentiates engineering from the mathematical-logical intelligence as he lists it as a career choice for those with spatial ability. Other careers involving spatial ability are architect, graphic artist, art teacher, and cartographer. Career choices for those who score high in mathematical-logical ability are mathematician, scientist, and computer analyst which requires computer programming. At any rate, mathematical-logical problem solving has been granted center stage in computer programming.

In the software engineering process, one begins with a purely conceptual view of the problem. The engineering approach places the emphasis on the design process, a very creative endeavor, where many "what-if" questions are asked (Pothering and Naps, 1995). Software design involves functional specifications which are detailed enough to allow translation to the structural descriptions of a computer program to solve the problem (Nelson, 1988). Many colleges and universities require completion of at least two semesters of calculus for a degree in computer science and, thus, emphasize the mathematical and logical reasoning required for computer programming. Few, if any, require a class in art, creative design, or creative thinking. Does the old adage, "Computer programming is an art as well as a science.", have any significance?

The problem-solving ability associated with mathematical and logical reasoning have long been associated with computer programming. Psychologists have described the stages of problem solving as understanding the problem, followed by generating hypotheses and choosing among alternatives, and finally as testing and evaluating the solution (Nelson, 1988). These same steps are generally the ones given to beginning computer programming students.

Although computer science has been associated with mathematical and logical ability since its introduction into the colleges and universities, it was not until the 1980's that educational studies which begin relating problem solving and computer programming appeared on the scene. In 1984 Galanter stated that programming languages may be the language of "operational logic" (p. 31), an area that is often overlooked in schooling. McCoy and Orey (1987) concluded that while problem-solving ability is the best predictor of computer programming achievement, programming instruction has a positive effect on problem-solving ability.

One study comparing the effects of BASIC and Logo programming on problem-solving skills (Reed, Palumbo, and Stolar, 1988) concluded that while both increased problem-solving ability, there was no significant difference in the two. Both of these languages were taught with a top-down approach to promote modularity, and both have limited logical constructs. Another study (Reed and Palumbo, 1988) found a significant, negative relationship between computer anxiety and problem solving, concluding that, as computer anxiety decreased, problem-solving ability increased. They found positive relationships between problem solving, debugging, programming, and prior programming experience.

A 1991 study by Palumbo and Reed compared problem-solving increases in high school students enrolled in either a 16-week BASIC programming class or a 16-week computer literacy class. The result showed no significant gain in the problem-solving skills of the computer literacy group but a significant gain in the problem-solving skills of the BASIC programming group. Students who more completely learned the BASIC programming language also solved problems more effectively. A follow-up study (Reed and Palumbo, 1992) concluded that student programmers have to accommodate computer anxiety before they can focus on learning the language.

One study (McCoy and Dodl, 1989) indicated that 60.6% of the variance in mathematical problem-solving could be contributed to ability, gender, mathematics experience, and programming experience. Ability had the greatest effect; gender, mathematics experience, and computer programming experience had moderate significant effects.

Norris, Jackson, and Poirot (1992) found after a one-semester programming course, significant improvement in scores on both the Watson-Glaser Critical Thinking Appraisal and the Thurstone Test of Mental Alertness occurred. Since both tests are of a general nature, the problem-solving and critical thinking abilities gained in a computer programming class are transferable. A significant increase in problem-solving skills in college students occurred when the language of instruction was either FORTRAN or Pascal although no difference in problem solving was observed between the groups (Choi and Repman, 1993).

The results of these studies clearly indicate that programming experience does increase problem-solving ability. On the other hand, the studies do not indicate what it takes to be a good programmer. It is generally taken for granted that mathematical-logical intelligence is the basis for computer programming. However, the availability of a graphic representation can aid the design process (Carroll, Thomas, and Malhotra, 1980). These researchers further concluded that certain problems and their presentations encourage graphic representation and are more easily solved through this graphic representation. At the same time, exceptional teachers of computer science have made statements that resemble: "Computer programming is an art as well as a science" (Wirth, 1986; Yohoe, 1974). "The real work of design, then, is involved with the creative process" (Nelson, 1988, p. 215). Such statements would seem to imply an artistic side of computer programming.

Computer programming students enrolled in computer graphics classes need spatial skills. However, the programming of rotations, reflections, and mirror images require mathematical formulas. The testing of these transformations do require spatial skills as one has to be able to predict what the transformation should look like in order to see if the code is correct. It would seem that the appearance of visual languages, such as Visual Basic, Visual C++, and Visual Pascal, would also require spatial skills which exceed those of other programming languages.

When computer technology is used in the classroom, good students tend to overcome the initial barriers (accessing the system, anxiety, keyboarding and mouse skills) and excel even more. Poor students become frustrated by the technology, and some of these even do worse (Norman, 1994). Two factors, spatial visualization and vocabulary, were found to be the only significant contributors to the variance. Spatial visualization contributed most to this variance (Vicente, Hayes, and Williges, 1987). Subjects with low spatial ability took twice as long to perform a task and got lost at all levels while trying to find information. Other studies have supported this correlation between spatial ability and navigating hypermedia systems with correlations as high as 0.64 (Butler, 1990; Norman and Butler, 1989). Users with low spatial visualization need to be able to rotate, re-arrange, and sequence images on the screen rather than in their heads.

When field independence / dependence was used as a factor in using hypermedia instruction, field-dependent students sought information in an opposite manner than did field-independent students. The frequency of accessing information was also related to whether the student was field-independent or dependent. Field-dependent learners did not learn as successfully as field-independent learners regardless of the type of organizer presented in the software (Weller, Repman, and Rooze, 1994). Stanney and Salvendy (1995) suggest that a menu hierarchy in software accounts for the difference in computer performance between field-dependent and field-independent persons. The field-independent person perceives the hierarchical menu system using an analytical approach and tries to construct a mental hierarchy of the system. The field-dependent person perceives the information but does not construct an integrated model of the hierarchy.

When global interface is used to represent the whole of a hypernetwork and local interface is used to represent only two nodes from the network at a time, students using the local interface demonstrated significant positive pre-test / post-test differences. However, students who used the global interface demonstrated significant negative pre-test / post-test differences (Lidwell, Palumbo, and Troutman, 1994). It appeared that students who interacted with the global interface retained strong visual-spatial impressions of the map although they failed to understand the relationship among the nodes. The main difference in the interfaces was the local interface presented a choice of two nodes while the global interface permitted users to access 18 nodes.

Results of a study of gifted adolescents showed that CAD instruction did not improve their spatial visualization ability. Neither was the spatial visualization of these students related to gender, grade level, GPA, semesters of computer courses, or semesters of drafting courses (Mack, 1994). It is interesting to note that a relationship between spatial visualization and gender was not found in this study. However, the study group consisted of 14 males and six females who selected the CAD class.

Stanney and Salvendy (1995) demonstrated the ability to accommodate low spatial individuals in information search environments through the use of visual mediators. When using a visual interface similar to a table of contents in a book, low spatial individuals performed slightly faster than high spatial individuals. However, when the interface required the mental construction of a model of the organization, high spatial individuals outperformed the low-spatial group by 18%.

Another study (Kiser, 1990) involved two groups of students, solving linear absolute-value inequalities. One group used computer-enhanced instruction, and one received traditional instruction. The conclusion was that spatial visualization was a significant predictor of achievement in the computer-enhanced instruction group but not the traditional group.

DeNardo and Pyzdrowski (1994) used computer simulators in a computer architecture class and concluded that the simulators benefitted the students. Furthermore, the low and medium ability groups benefitted the most. The authors suggest that more research should be done in this area. It may also be possible that, to have reached this level in the computer science field, these students have always had or have gained many spatial skills.

Mack (1994) suggests that studies to determine the correlation between spatial visualization and problem-solving abilities should be done. He also suggests that since spatial visualization is a multi-dimensional ability, it should be measured by more than one instrument. Furthermore, he suggests that computer experience should be considered as specific experiences. To illustrate the idea of specific experiences, the question of whether word-processing experience and computer graphics experience will contribute equally to development of spatial visualization skills is asked. Other questions lacking answers (Davidson, Savenye, and Orr, 1992) are how learning styles may be a predictor of successful performance in a computer course; what learner characteristics, such as gender and ability, characterize the way students learn and process information?

Results of Pilot Studies

A spring, 1996 pilot study performed at a small university which uses the modular system consisted of a sample of 14 students enrolled in one or more computer science classes. Results of this study indicated that mathematical-logical intelligence is more important than spatial intelligence in predicting success in computer programming. This study also looked at field dependence / independence as measured by the Group Embedded Figures Test (GEFT) and concluded that field-independent students are more successful in computer programming than are field-dependent students (Table 1). A significant positive correlation was found between ACT / SAT mathematics scores and computer programming ($r = .785$). In this study, a test, constructed by the author, to measure spatial skills was used. Results showed no significant correlation between spatial skills as measured by this instrument and the course grade. However, there was a significant positive correlation between this constructed test and the GEFT ($r = .513$). Seven students were given a questionnaire to measure their self-perception of their seven intelligences. There was no significant correlation between the students' mathematical perception of their ability and their mathematics score on the ACT / SAT mathematics score. A significant correlation (r = .667) was found between the students' self-perception of their spatial ability and the GEFT score.

Table 1

Correlations Among Measurements
Spring, 1996

Measure	Visual	Course Grade	ACT / SAT Math Score
	n=14	n=14	n=11
GEFT	.51**	.52**	.63**
Visual		.26	.47
Grade			.79*

*$p < .01$. **$p < .05$.

A follow-up study was performed in the fall of 1996 at the same university, using some of the same students involved in the previous study. However, this study also included students enrolled in a beginning programming course rather than just those who had already passed the beginning course. The sample size in this study was 24, but two students were eliminated as they had completed only two of the five measures. The sample size of 22 (13 males and nine females) was used in most measurements, but three students had not taken the ACT or the SAT and were eliminated from all measurements involving this measure. Similarly, three students did not take the Cube Comparisons Test (S-2) and were eliminated from scores involving it. In all cases the sample size was 16, 19, or 22.

Measurements used in this study were: (1.) ACT or SAT mathematics score; (2.) ACT English or SAT Verbal score; (3.) course grade; (4.) self-perception questionnaire of the seven intelligences (Armstrong, 1994); (5.) Cube Comparisons Test, a measure of spatial orientation, (S-2, Educational Testing Service, 1976); (6.) Map Planning Test, a measure of spatial scanning, (SS-3, Educational Testing Service); and (7.) Paper Folding Test, a measure of visualization, (VZ-2, Educational Testing Service). A questionnaire was administered to gather the following information: age, year in school, sex, previous mathematics experience by checking number of courses completed, number of students in their high school, whether or not they owned a computer, whether or not they had ever taken an art course, and their experience with computer use in the areas of word-processing, spreadsheets, game-playing, databases, drawing programs, presentation packages, publishing packages, and programming experience (students rated this experience on a scale of 0-5). As students rated their own computer experience, the measure may not have been very accurate since it was noted that in the area of programming experience, advanced students did not rate their experience as high as some of those who were enrolled in the beginning programming course. It may be that students with more experience realized that they have much more to learn than do those in a beginning course.

Table 2

Correlations of Students' Perceived Intelligences with Measurements Fall, 1996

	n=22			n=19		
Perceived Intelligence	Course Grade	Spatial Scanning	Visual-ization	Spatial Orient	ACT Eng	ACT Math
Linguistic	.05	-.08	.20	-.10	.24	-.09
Mathematical	.45*	.13	.11	.33	.09	.53*
Spatial	.41**	.05	.14	.15	.05	.39**
Bodily	-.05	-.16	-.32	-.08	-.14	-.12
Musical	-.01	-.01	-.05	-.07	.21	.03
Interpersonal	.10	-.13	-.23	.08	-.02	.02
Intrapersonal	.04	-.18	-.11	.00	.31	.17

*$p < .05$. **$p < .10$.

When students' self-perception of their seven intelligences was used as a measure, some interesting correlations were observed (Table 2). Significant positive correlations existed between students' perception of their mathematical-logical ability with the course grade (r = .45) and the ACT / SAT mathematics measure (r = .53). Students' perception of their spatial ability had positive significant correlations with their course grade (r = .41) and the ACT / SAT mathematics measure (r = .39). A slightly negative correlation existed between their perception of bodily / kinesthetic intelligence and the course grade, the spatial scanning (Map Planning) test, the ACT mathematics measure, the ACT English measure, and the spatial orientation (Cube Comparison) test. A slightly higher, yet non-significant negative correlation (r = -.32) was found between the visualization (Paper Folding) test and the perception of bodily / kinesthetic intelligence.

Significant positive correlations were found between completion of Calculus 1 (Table 3) and the course grade (r = .67), the visualization test (r = .49), spatial orientation test (r = .76), the ACT English score (r = .48), and the ACT mathematics score (r = .63); the

Table 3

Correlations of Measurements with Students' Estimation of Their Experiences Fall, 1996

	n=22			n=19		
[a]Personal Information	Course Grade	Spatial Scanning	Visual-ization	Spatial Orient	ACT Eng	ACT Math
[b]Total Math	.65*	.17	.22	.34	.22	.63**
Calculus 1	.67*	.29	.49***	.76*	.48***	.63**
Calculus 2	.47***	.06	.20	.31	.11	.40****
Word Proc.	.49***	.41****	.44***	.14	.10	.22
Comp Draw.	.44***	.21	.57**	.64**	.19	.38****

Items whose correlations were nearly or totally insignificant or correlated with only one item were not included.
[a] Personal Information is completion of the course (math) or perceived experience (computer)
[b]Total Math is total number of math course completed
*$p < .001$. **$p < .01$. ***$p < .05$. ****$p < .10$.

only test measurement that it did not correlate with was the spatial scanning score.

These results seem to imply that completion of a Calculus 1 course might be valuable in several areas, or they might illustrate that students who complete a Calculus 1 class have acquired skills in several areas, or as Gardener (1983) stated, language is essential for the mathematical-logical intelligence. The only other item that correlated significantly with more than three items was computer experience with drawing programs which positively correlated with the course grade (r = .44), the visualization test (r = .57), the spatial orientation test (r = .64), and the ACT mathematics measure (r = .38).

Significant positive correlations were found between a student's course grade (Table 3) and the number of mathematics classes completed (r = .65), the total amount of self-measured computer experience (r = .47), completion of a geometry course (r = .41), completion of Calculus 1 (r = .67), completion of Calculus 2 (r = .47), word-processing (r = .49), spreadsheet (r = .36), drawing programs (r = .44), and programming experience (r = .40). When correlated with other measures (Table 4), the course grade was found to have significant correlations with the spatial orientation test (r= .71), the visualization test (r = .58), the ACT English measure (r = .41), and the ACT mathematics measure (r = .83). Since the course grade correlated with several variables, it may be that success in a computer programming course cannot be predicted by the use of just a few variables, but may require many.

Table 4

Correlations Among Measurements Fall, 1996

	n=22		n=19		
Measure	Spatial Scanning	Visualization	Spatial Orient	ACT English	ACT Math
Grade	.30	.58**	.71*	.41***	.83*
Sp SC	---	.66*	.37	-.25	.20
Visual	---	----	.78*	.26	.58**
Sp Or	---	---	----	.41	.64**

*p < .001. **p < .01. ***p < .10.

Although correlations were found between the students' self-perception of their mathematical-logical intelligence and spatial intelligence with both the course grade and the ACT mathematics measure in the fall study, no such correlations existed in the spring study. This may be due to the difference in sample sizes as the spring study used a very small number of students for their self-perception measure while the fall study used more students. All students who completed the self-perception measure in the spring study were involved in the fall study.

It is interesting that the measure for spatial scanning (Map Planning Test) correlated positively with only the visualization (Paper Folding Test) ($r = .66$) measure and word-processing experience ($r = .41$). Word-processing experience also correlated positively with the course grade and the visualization measure, but it did not correlate with either of the ACT measures or the spatial orientation (Cube Comparisons Test) measure.

No sex differences were found to exist or even approach significance in any of the measures. This may be due to the type of females who self-select a computer programming course or major. Or as some other recent studies have shown, it may be that females, being tested, are no longer deficient in spatial skills. Other personal information that did not correlate with any of the measures was year in school, ownership of a computer, completion of an algebra class, the number of advanced (after Calculus 2) math classes completed, experience in playing computer games, using a publishing package, presentation package, or databases.

Differences in Pilot Studies and This Study

Both pilot studies involved only students enrolled in a computer science course. These students either were computer science majors or had planned to be computer science majors at the time. This study involved both computer science majors and a group of non-majors enrolled in a statistics course.

The spring study used the GEFT to measure field dependence / independence; the fall study did not use the GEFT. The GEFT has a reliability estimate of 0.82 (Witkin et al., 1971). The visualization test used in the spring was constructed by the author and had no reliability or validity ratings. The spring study used no measures of spatial scanning or spatial orientation. The three tests, visualization test (Paper Folding Test, VZ-2), the spatial orientation test (Cube Comparisons Test, S-2), and the spatial scanning test (Map Planning test, SS-3), used in the fall study are from ETS. Reliability ratings for the Paper Folding Test, the Cube Comparisons Test, and the Map Planning Test are given as 0.84 (males and females), 0.84 (males) and 0.47 (females), and 0.79 (males and females), respectively. These tests have construct validity when used to classify factors; however, one should be aware that truly pure "factors" probably do not exist (Ekstrom, French, Harman, and Dermen, 1995). The GEFT and different versions of tests from ETS to measure visualization, spatial orientation, and spatial scanning will be used in the proposed study.

This study allowed comparison between computer science majors and non-majors in the areas of field dependence / independence, visualization, spatial scanning, and spatial orientation. In addition, it compared advanced computer science majors to less advanced computer science majors. Neither of the pilot studies was designed to allow these comparisons.

Chapter 3

Design of the Study

Purpose of the Study

The purpose of this study was to determine if spatial intelligence contributes to a student's success in a computer science major or if mathematical-logical intelligence is sufficient data on which to base a prediction of success.

Research Questions

The research questions were: (1.) Is there a difference between computer science majors and non-majors in terms of: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences? (2.) Is there a difference between advanced computer science majors and less advanced computer science majors, measured by the number of computer science courses completed, in terms of: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences? (3.) Among computer science students, what correlations exist: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; (e) self-perception of intelligences (7 factors); (f) year in college; (g) number of students in high school; (h) math courses (geometry, Algebra 2/ College Algebra, Calculus 1, Calculus 2, statistics, higher level college math courses); (i) computer experience (word-processing, spreadsheets, game-playing, publishing applications, databases, drawing programs, presentation packages, programming experience); (j) computer ownership; and (k) completion of an art course or art workshop? (4.) How do the ACT / SAT scores of computer science majors correlate with: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences?

Design of the Study

This study was performed at a small university which uses the modular system for courses. The modular system is organized such that a student takes one four-credit class during one module (mod). A mod consists of 18 consecutive class days or three weeks and three days. The duration of the class each class day is generally between three and four hours. The other type of class is a multi-mod class. A multi-mod class exists for three regular modules. Although the number of contact hours in a multi-mod and a regular mod are the same, the multi-mod has a duration of 12 weeks and is offered as an evening or night course. In a 12-week time frame, a student can complete 16 credits of courses if he / she takes three regular mod courses and a multi-mod course.

The courses used in the study were used merely to access a sample. Testing and completion of questionnaires could not be done simultaneously as all courses used in the study did not exist at the same time. The duration of the study was two weeks and consisted of two computer science courses for majors and one competency course, which is required for all students in the university.

Sample

The sample consisted of computer science majors in two different computer science classes, a discrete math course which includes most freshmen and sophomore computer science majors and a computer architecture course which consisted of advanced students. There was some overlap as a few advanced students were enrolled in both courses. These students were tested in only the first of the two courses in which they were enrolled. A comparison sample was obtained from a statistics class. A statistics class permitted a sample of the general university student as every student enrolled in the university is required to take statistics. There were no computer science majors enrolled in the statistics course. Since there were more students (19 total) enrolled in the statistics course than there were computer science majors (15 total), students in the statistics class were matched as nearly as possible to computer science majors by year in school, age, and sex. Four of the non-CS-majors were eliminated after the matches were made.

Independent Measures

The mathematics and the English / verbal part of the student's ACT / SAT score. These ACT / SAT scores were used as a measure of mathematical-logical intelligence and of linguistic intelligence. Some students are not required to take these tests for admission into the university.

A questionnaire to obtain personal information (Appendix A). Information about year in school, age, sex (code: 0 = male, 1 = female), number of students in their high school (code: 1 = < 500, 2 = 501-750, 3 = 751-1000, 4 = > 1000), amount and type of math classes completed, amount and type of computer experiences, computer ownership (0 = not own, 1 = own), completed art course or workshop (code: 0 = no art, 1 = 1 or more), and college major were collected on this questionnaire.

Major area of study. Computer Science (CS) majors were compared to non-CS-majors across the dependent measures.

Level of computer science experience. Advanced computer science majors were compared to less advanced computer science majors. This was determined by the number of computer science courses completed. Students who had completed more than five computer science courses, excluding the one in which they were enrolled, were considered advanced.

Dependent Measures

A Multiple Intelligence Inventory for Adults. This questionnaire is presented in Armstrong (1994, p.18). The space for additional comments at the end of each intelligence was omitted as well as the titles for the type of intelligence being determined. This inventory is in a checklist questionnaire form and does not have validity or reliability coefficients. Direction to the students is to check statements that apply to them. There are 10 statements pertaining to each intelligence, and each statement checked is counted as one point which results in a range of 0 to 10 for perception of each intelligence. A sample statement for linguistic intelligence is: "Books are very important to me" (Armstrong, p. 18), and a sample statement for spatial intelligence is: "I often see clear visual images when I close my eyes" (Armstrong, p. 18).

GEFT, Group Embedded Figures Test. This test was given to determine field dependence / independence and to look for relationships between it and other forms of spatial visualization as well as the course grade. The GEFT is a standardized test that requires the location and tracing of one of eight forms included in a complex form. The testing time is 10 minutes, and the range of scores is 0 to 18. This test consists of a practice section and two sections of nine problems each. The score is obtained by the number of correct drawings in the two sections. The highest possible score is 18. The GEFT has a reliability estimate of 0.82 (Witkin et al., 1971).

Performance on the test was first used as an indicator of the field dependence / independence cognitive style and later as an indicator of ability to solve problems analytically rather than globally. One study (Howe and Doody, 1989) showed that performance on the GEFT indicated that the disembedding ability required is not an aspect of spatial ability but is a manifestation of problem-solving ability or fluid intelligence. This study illustrated that 22% of the variance in GEFT scores could be accounted for by Cognitive Regulation. The other significant part of the score is accounted for by complex imagery although the percentage accounted for is not given. Howe and Doody did not find significant differences in gender performance on the GEFT as in previous studies (Witkin et al., 1971).

Card Rotations Test (S-1). This is a test for spatial orientation and is designed to test a subject's ability to perceive spatial patterns or to maintain orientation with respect to objects in space. Each item gives a drawing of a card cut into an irregular shape. To its right are six other drawings of the same card, either rotated or turned over. The subject indicates whether or not the card has been turned over or simply rotated. There are two parts to the test, each contains 10 items and the time allotted for completion is three minutes for each part. Scoring is done by subtracting the number of wrong answers from the number of right answers resulting in a possible range of -120 to +120. The reliability estimate for this test is 0.80 for males and 0.83 for females. Just how this factor is related to visualization seems to vary among different researchers. This test, as well as all other tests in the Kit of Factor-Referenced Cognitive Tests (ETS), has construct validity when used to classify factors; however, one should be aware that truly pure "factors" probably do not exist (Ekstrom et al., 1995).

Maze Tracing Speed Test (SS-1). This is a test for spatial scanning which is the speed in exploring visually a wide or complicated spatial field. This factor has sometimes been interpreted as a planning function although the level of planning seems to be a willingness to find a correct path visually before wasting time in marking the path. The task is to find and mark a path through a moderately complex series of printed mazes. The test is presented in two parts, each of which has four scorable units. The time to complete each part is three minutes. Scores are calculated by the number of squares through which a line has been correctly drawn. The range of scores is 0 to 48. The reliability estimate is given as 0.94 for both sexes (Ekstrom, et al, 1995).

Surface Development Test (VZ-3). This is listed as a visualization test which tests the ability to manipulate or transform the image of spatial patterns into other arrangements. Although the visualization and spatial orientation factors are similar, the difference seems to be that visualization requires that the figure must be mentally broken into components for manipulation while spatial orientation involves manipulation of the whole figure. A drawing on a piece of paper is presented with dotted lines indicating where the folds are to be and some of the edges are numbered. To the right of this plane figure is a drawing of a solid figure made from the plane figure with lettered edges. One is to match the numbered edges of the plane figure with the lettered edges of the solid figure. This test is presented in two parts, each containing six drawings of which five edges must be matched; six minutes is allotted for completion of each part. Scores are obtained by subtracting one-fourth of the number of wrong answers from the number of correct answers resulting in a range between -15 and +60. The reliability estimate is given as 0.90 for males and 0.92 for females (Ekstrom et al, 1995).

Procedures

Each student was told about the study (Appendix B) on the day that the study began in that class. On that day, they were asked to complete the questionnaire, the multiple intelligence inventory, the GEFT, the Card Rotations Test (S-1), the Maze Tracing Speed Test (SS-1), and the Surface Development Test (VZ-3). These questionnaires and tests were administered by a faculty member who was not the instructor of the course and was not the researcher.

Analysis of the Data

Unpaired t-tests were used to determine if there were significant differences between CS-majors and non-CS-majors in the areas of: (a) field dependence / field independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences (7 items). Unpaired t-tests were used to determine if there were significant differences between advanced CS-majors and less advanced CS-majors in the areas of: (a) field dependence / field independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; (e) ACT / SAT scores; and (f) self-perception of intelligences (7 items).

The Pearson r correlation coefficient was used to determine correlations among computer science students involving: (a) field dependence / field independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; (e) self-perception of intelligences (7 factors); (f) year in college; (g) number of students in high school; (h) math courses (geometry, Algebra 2 / College Algebra, Calculus 1, Calculus 2, statistics, higher level college math courses); (i) computer experience (word-processing, spreadsheets, game-playing, publishing applications, databases, drawing programs, presentation packages, programming experience); (j) computer ownership; and (k) completion of an art course or art workshop. The Pearson r correlation coefficient was used to determine ACT / SAT correlations among computer science students and: (a) field dependence / independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences.

Chapter 4

Results

On March 26, 1997, the script was read to the students in the computer architecture class. After that the personal data questionnaire, the multiple intelligence inventory, the GEFT, the Card Rotations Test (S1), the Maze Tracing Speed Test (SS1), and the Surface Development Test (VZ3) were administered to these students. On April 8, 1997, the script was read to the students in both the discrete mathematics class and the statistics class. Following that the questionnaire, inventory, and tests were administered to students in both classes. Since the discrete mathematics class included some students who had been enrolled in the computer architecture class, these students were given a break during the testing of the other students. The statistics class was smaller than most statistics classes, consisting of 19 students (11 males and eight females), and did not include any computer science majors. The computer science majors consisted of 12 males and three females.

Research Question One

Research question one was: Is there a difference between computer science majors and non-majors in terms of: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences? To answer this question, a group from the statistics class was matched as closely as possible on sex, year in college, and age to computer science majors. All three items were examined to create as nearly equal pairings as possible on sex, age, and year in college. Since there was one more male in the group of CS-majors than non-CS-majors, one female (non-CS-major) was matched with one male (CS-major). The remaining four from the non-CS-major group were eliminated. Independent samples t-tests were run on the data. There were no significant differences (Table 5) in age, year in school, or sex although age approached significance. Most of this can be attributed to one computer science senior who was four years older than the average college senior (22 years) and the rest to the year difference in age due to when birthdays fall throughout the

Table 5

Results of Independent Samples T-Test on Questionnaire Data
(CS-Majors and Non-CS-Majors)

Item	CS-Major Mean	CS-Major SD	Non-CS-Major Mean	Non-CS-Major SD	T Score	p<
School Yr	2.47	1.31	2.20	1.33	0.55	
Age	20.53	2.22	19.80	1.56	1.05	
[a]Sex	0.20	0.40	0.27	0.44	-0.43	
[b]Hi. Sch. Sz.	2.8	1.11	2.47	1.20	0.79	
Calculus 1	0.73	0.44	0.33	0.47	2.40	0.05
Calculus 2	0.40	0.49	0.27	0.44	0.78	
> Calcu. 2	0.33	0.47	0.00	0.00	2.74	0.05
[c]Total Math	5.60	1.67	3.93	1.57	2.82	0.01
Word-Proc	4.20	0.83	3.80	1.47	0.91	
Spreadsheet	3.20	1.05	1.80	1.47	3.00	0.01
Games	4.60	0.71	4.13	1.36	1.18	
Publishing	2.80	1.22	1.80	1.64	1.89	0.10
Database	3.07	1.00	1.40	1.40	3.75	0.001
Drawing	3.27	1.18	2.07	1.57	2.37	0.05
Progrmming	3.60	0.71	0.60	0.95	9.77	0.001
Presentation	2.67	1.08	1.00	1.32	3.80	0.001
[d]Own Comp	0.73	0.44	0.67	0.47	0.40	
[e]Art	0.40	0.49	0.53	0.50	-0.74	

[a] 0 = Male; 1 = Female;
[b] 1 = <500 students; 2 = 501-750; 3 = 751-1000; 4 = >1000;
[c] Total number of math courses checked as completed
[d] 0 = does not own computer; 1 = does own computer;
[e] 0 = has not completed art course/workshop; 1 = has completed art course/workshop

year. For example, if a student celebrated a birthday in March, the student would have listed his / her age as 19 while one celebrating a birthday in mid to late April would have listed his / her age as 18, because of timing of the data collection.

As was expected, there was a significant difference in computer programming experience (Table 5). In general computer use, CS-majors also had significantly more experience with spreadsheets, publishing packages, databases, drawing software, and presentation packages than non-CS-majors. In terms of word-processing and games, there was no significant difference in perceived experience. Since three calculus courses

Table 6

Results of Independent Samples T-Test on Measures and Perception of Intelligences (CS-Majors and Non-CS-Majors)

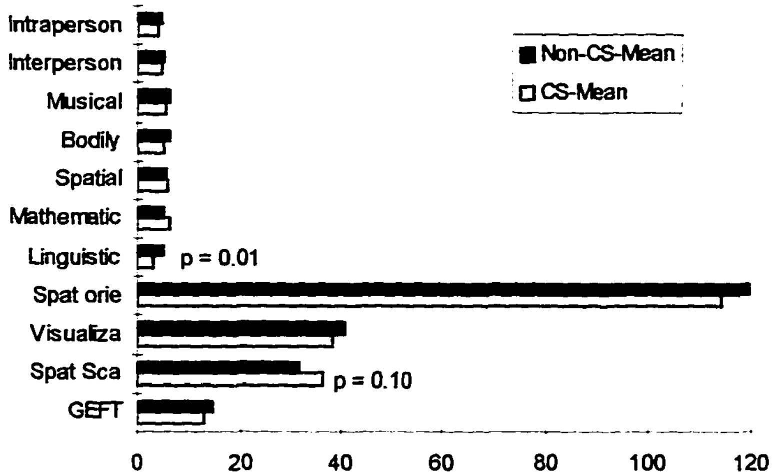
	CS-Major		Non-CS-Major			
Item	Mean	SD	Mean	SD	T Score	p<
GEFT	13.07	3.97	14.67	2.98	-1.25	
Spat Scan	36.47	6.08	31.80	7.83	1.82	0.10
Visual	38.63	18.33	40.97	14.60	-0.39	
Spat Orien	114.07	31.45	119.60	33.76	-0.46	
Linguistic	3.13	1.67	5.00	1.51	-3.22	0.01
Math-Log	6.20	2.32	5.13	2.50	1.21	
Spatial	5.73	2.82	5.53	1.41	0.25	
Bodily	5.07	2.49	6.20	2.20	-1.32	
Musical	5.67	3.03	6.13	2.75	-0.44	
Interperson	4.80	2.26	5.26	1.48	-0.67	
Intraperson	4.07	2.29	4.80	2.26	-0.88	

p = significance level of two-tailed independent samples t-test

and another advanced mathematics course are now required for computer science majors (this does not include juniors and seniors as the program was changed after they entered to include more mathematics), it is not surprising that CS-majors had completed significantly more mathematics courses than non-CS-majors.

Figure 1

Means of CS-Majors and Non-CS-Majors on Measues and Perception of Intelligences



p = significance level of two-tailed independent samples t-test.

Although non-significant but approaching significance (Table 6, Figure 1), non-CS-majors scored higher than CS-majors on the GEFT, a test for field dependence / independence. While scoring the GEFT, I observed that two CS-majors found the correct shape in the correct size but with the wrong orientation in at least one or more figures. This was not observed among any of the non-CS-majors.

There was no significant difference in the groups on the spatial orientation measure or on the visualization measure (Table 6, Figure 1). There was a significant difference ($p= 0.10$) in the groups on the spatial scanning measure with CS-majors scoring higher than non-CS-majors. This test is designed to measure the speed in exploring visually a wide or complicated spatial field.

A significant difference (Table 6, Figure 1) in self-perception of linguistic intelligence existed with non-CS-majors having a higher perception of their linguistic intelligence. None of the other self-perception of intelligences showed a significant difference. However, the direction of the t-score (Table 6) indicates that CS-majors perceived a higher level of mathematical and spatial intelligence while non-CS-majors perceived a higher level of the other five intelligences, linguistic, bodily, musical, interpersonal, and intrapersonal.

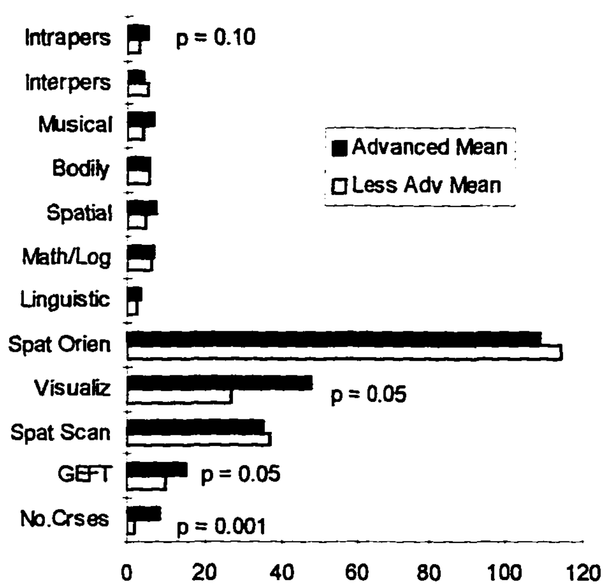
The answer to research question one was, there was a significant difference on the spatial scanning measure with CS-majors scoring higher than non-CS-majors. The only other significant difference in answer to the question was that non-CS-majors perceived a higher level of linguistic intelligence than did CS-majors.

Research Question Two

Research question number two was: Is there a difference between advanced computer science majors and less advanced computer science majors, measured by the number of computer science courses completed, in terms of: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences? The computer science sample consisted of 15 students;

Figure 2

Means of Advanced and Less Advanced Majors on Measures and Perception of Intelligences



p = significance level of two-tailed independent samples t-test however, one of these students was eliminated when comparing the two groups. The reason for elimination was that although he had been enrolled in five courses, he had not passed all five courses. Since the difference in the number of courses taken was distinct with less advanced students completing between one and four courses and advanced completing between six and 12 courses, independent samples t-tests (Figure 2, Table 7) were run on the data to answer the research questions.

Advanced CS-majors scored significantly higher than less advanced CS-majors on the GEFT. Thus, advanced CS-majors were more field independent than non-advanced CS-majors. Advanced CS-majors also did significantly better on the visualization test.

Table 7

Results of Independent Samples T-Test on Measures and Perception of Intelligences (Advanced and Less Advanced CS-Majors)

Item	Less Advanced Mean	Less Advanced SD	Advanced Mean	Advanced SD	T Score	p<
No. Classes	2.14	0.83	8.29	2.05	-6.80	0.001
GEFT	10.29	3.28	15.14	2.75	-2.78	0.05
Spat Scan	37.14	5.74	35.29	6.52	0.52	
Visual	27.07	20.20	47.61	7.14	-2.35	0.05
Spat Orien	114.14	26.25	108.86	34.91	0.30	
Linguistic	2.43	1.84	3.86	1.25	-1.57	
Math-Log	6.14	2.23	6.71	2.19	-0.45	
Spatial	4.71	2.71	7.14	2.36	-1.66	
Bodily	5.71	1.91	5.71	3.10	0.00	
Musical	4.29	3.06	7.00	2.56	-1.67	
Interpersonal	5.42	2.06	4.43	2.38	0.78	
Intrapersonal	3.00	1.85	5.29	2.25	-1.92	0.10

p = significance level of two-tailed independent samples t-test

Although non-significant, less advanced CS-majors did better on both the spatial scanning and the spatial orientation measures. This result was even more interesting since spatial scanning was the only measure that CS-majors scored higher on and that showed a significant difference when compared to non-CS-majors.

On the perception of intelligences, advanced CS-majors perceived a significantly higher intrapersonal intelligence. It may be that the perception of intrapersonal intelligence becomes more prominent with either age or more education. The average age of less advanced CS-majors was 18.9 (range: 18-20) and advanced CS-majors was 21.9 (range:19-26). Less advanced CS-majors were either in their first or second year of college (mean = 1.28), and advanced CS-majors were in their second through fourth years (mean = 3.42). The means for bodily intelligence between the groups were identical. Although non-significant, but approaching significance, was the advanced CS-majors' perception of their linguistic, spatial, and musical intelligences.

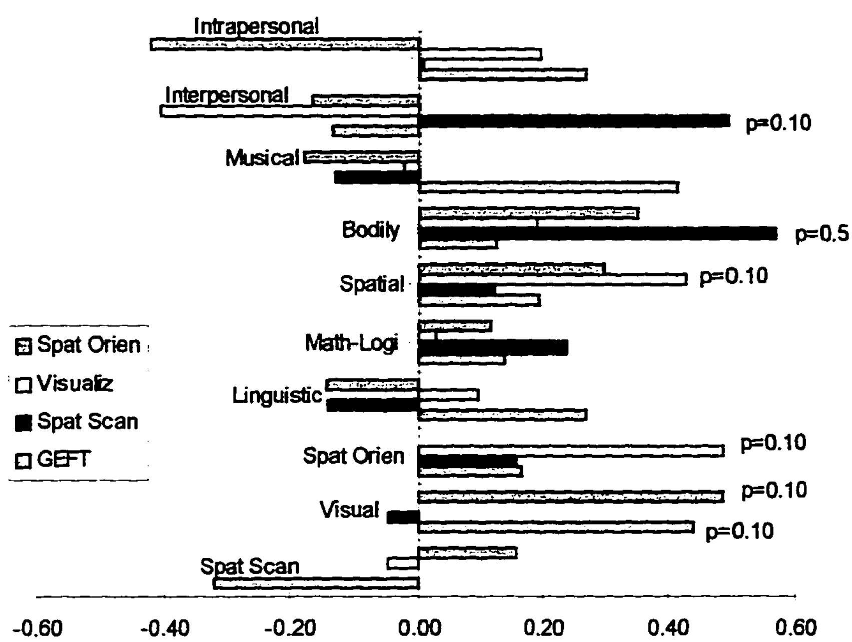
The answer to research question two was, that advanced CS-majors were more field independent, had better visualization skills, and perceived a higher level of intrapersonal intelligence than less advanced CS-majors.

Research Question Three

Research question three was: Among computer science students, what correlations exist: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; (e) self-perception of intelligences (7 factors); (f) year in college; (g) number of students in high school; (h) math courses (geometry, Algebra 2/ College Algebra, Calculus 1, Calculus 2, statistics, higher level college math courses); (i) computer experience (word-processing, spreadsheets, game-playing, publishing applications, databases, drawing programs, presentation packages, programming experience); (j) computer ownership; and (k) completion of an art course or art workshop? Significant correlations among the tests and the perceptions of intelligence (Figure 3) were both scant and relatively weak. The visualization measure (Figure 3) had significant positive correlations (p = 0.10) with the GEFT (r = .44), the spatial orientation measure (r = .49), and perception of spatial intelligence (r = .43). The spatial scanning measure correlated positively and significantly with perception of bodily intelligence (r = .57; p = .05) and perception of interpersonal intelligence (r = .49; p = .10). The negative non-significant correlation between the visualization and spatial scanning measures was in contrast to the fall study where the two measures correlated positively at a significance level of 0.001.

Figure 3

Correlations Among Measures and Perception of Intelligences for CS-Majors



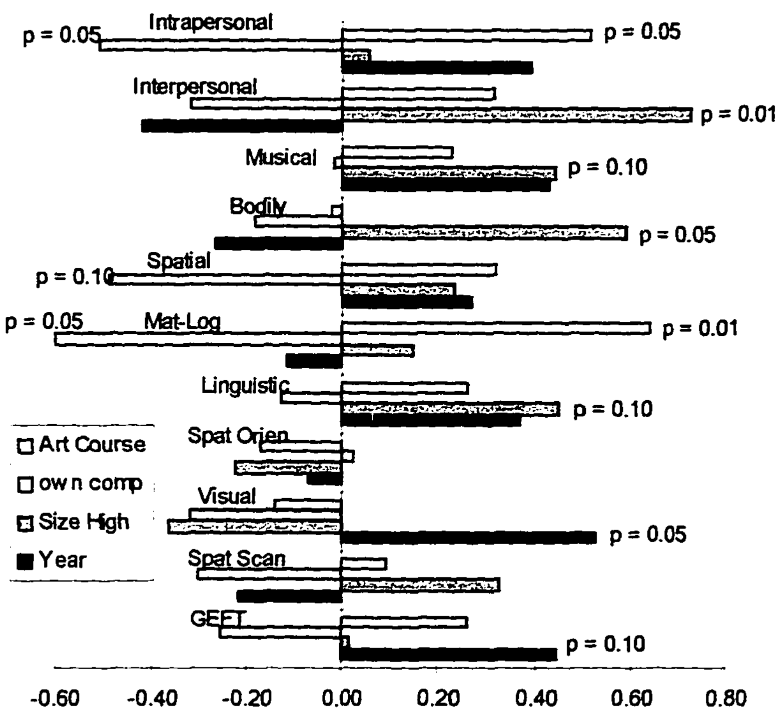
Significance of correlations are given at end of bars

The year in college (Figure 4) had positive significant correlations with the GEFT (r = .44; p = .10), the students' perception of musical intelligence (r = .43; p = .10), and the visualization measure (r = .52; p = .05). Although non-significant, the year in school correlated negatively with the measures for spatial scanning, spatial orientation, and perception of mathematical-logical intelligence.

Among CS-majors, the size of the high school had positive significant correlations with perception of linguistic, bodily, musical, and interpersonal intelligence. Students from larger high schools perceived higher degrees of these intelligences. Among non-CS-majors, the size of the high school (Figure C1, Appendix C) had positive significant correlations with perception of mathematical-logical intelligence and with the visualization measure. Although non-significant, the size of the high school had a

Figure 4

Correlations of Year in College, High School Size, Computer Ownership, and Completion of Art Course among CS-Majors



Significance of correlations are given at end of bars.

negative correlation with the visualization and spatial scanning measures among CS-majors. Since comparison of the two groups on the size of the high school correlation gave almost opposite results, correlations among all students (Figure D1, Appendix D) on the measures were performed. When using all students as the sample, the size of the high school correlated positively and significantly with the visualization measure, the perception of mathematical-logical, the perception of spatial, and the perception of intrapersonal intelligence. Therefore, nothing consistent can be stated about correlations among students from different size high schools in this study.

Although only three were significant, computer ownership (Figure 4) correlated negatively with all but one of the 11 measures. It correlated at a significance level of 0.05 with both perception of mathematical-logical and intrapersonal intelligence and a significance level of 0.10 with perception of spatial intelligence. Fortunately, this trend did not occur with non-CS-majors (Figure C1, Appendix C) as computer ownership correlated positively with perception of mathematical-logical and spatial intelligence. Only five of the 11 measures showed a negative correlation with computer ownership among non-CS-majors.

Completion of an art course or workshop (Figure 4) correlated positively and significantly with perception of mathematical-logical and intrapersonal intelligence among CS-majors. Among non-CS-majors (Figure C1, Appendix C), completion of an art course or workshop correlated positively and significantly ($p = .10$) with perception of linguistic intelligence and correlated negatively and significantly ($p = .10$) with perception of bodily intelligence.

Since most computer science majors had already completed College Algebra and all but one had completed geometry, any correlations with these two courses were probably just coincidental. In the fall study, completion of Calculus 1 had positive correlations with both the visualization measure and the spatial orientation measure at significance levels of 0.01 and 0.001, respectively; in this study, it had a correlation (Table 8) only with the spatial scanning measure, significant at the 0.05 level. Since the fall testing, several students completed both Calculus 1 and Calculus 2. Completion of Calculus 2 and total math courses completed correlated positively only with the perception of mathematical-logical intelligence.

Although statistics is a required course, completion of College Algebra is the only requirement for admission; thus, it can be taken in any sequence with the upper division mathematics classes. While seven of the 15 CS-majors had completed statistics, they were not all advanced students. Completion of statistics (Table 8) correlated positively with perception of linguistic and mathematical-logical intelligences at a significance

Table 8

Correlations of Mathematics Courses with Measures and Perception of Intelligences Among CS-Majors

Course	Calculus 1	Calculus 2	Statistics	>Calculus 2	Total
[a]Measure					
Spat Scan	.51***	.42	-.10	.26	.40
[b]Intelligence					
Linguistic	-.04	-.07	.49**	-.40	.20
Math-Logic	.39	.52*	.50*	.24	.61*
Spatial	.32	.22	.52*	-.03	.36
Intraperson	-.25	-.02	.56*	-.45**	-.08

[a] There were no significant correlations with the GEFT, Visualization, or Spatial Orientation Measures

[b] There were no significant correlations with Perception of Bodily, Musical, or Interpersonal Intelligences

*$p < .05$. **$p < .10$.

level of 0.10 and with spatial and intrapersonal intelligences at a significance level of 0.05. It is possible that the particular group that had completed statistics had a higher perception of these intelligences prior to taking the course or it could be that statistics influenced their perception of these intelligences. In the fall study, there were no correlations with completion of statistics. Since the sample of non-CS-majors were enrolled in a statistics class, no non-CS-major had completed a statistics class.

Self-perception of musical intelligence correlated positively with perceived levels of experience in word-processing, spreadsheets, publishing software, databases, and presentation software. Self-measured computer programming experience correlated significantly and negatively with perception of bodily intelligence. Although non-significant, but approaching significance, programming experience correlated negatively with interpersonal intelligence. Since employers often complain of the lack of "people skills" among computer programmers, this was an unfavorable statistic. This statistic was dubious as means of the less advanced and advanced CS-majors on self-measured programming experience were identical. It seems that less advanced CS-majors over estimated their experience.

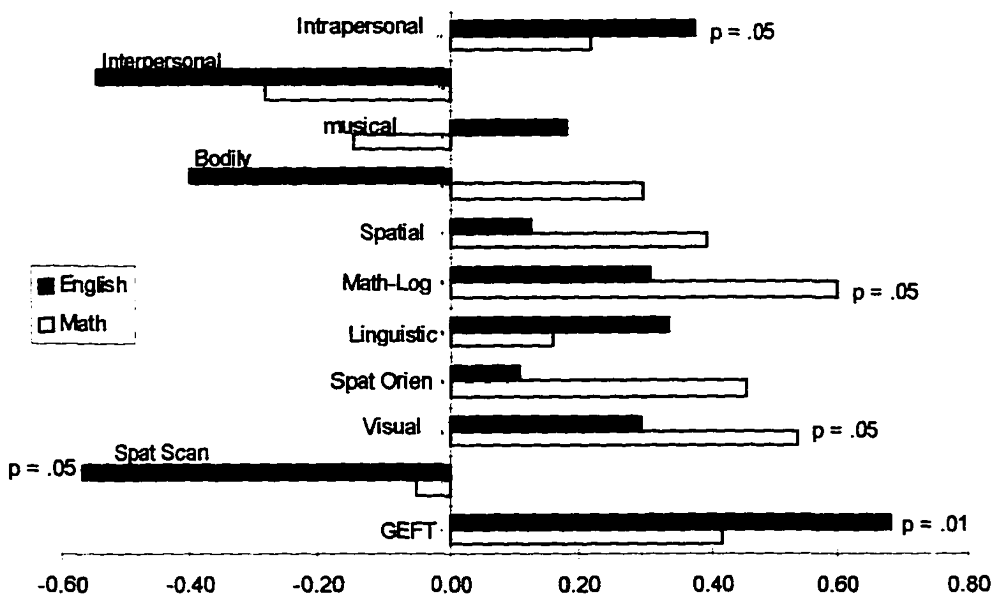
The answers to research question three were: (a) the visualization measure correlated positively with the GEFT, the spatial orientation measure, and perception of spatial intelligence; (b) the spatial scanning measure correlated positively with perception of bodily and interpersonal intelligence; (c) the year in school correlated positively with the GEFT, the visualization measure, and perception of musical intelligence; (d) completion of Calculus 1 correlated positively with the spatial scanning measure; (e) completion of Calculus 2 and more advanced mathematics courses correlated positively only with perception of logical mathematical intelligence; (f) completion of statistics correlated positively with perception of linguistic, mathematical-logical, spatial, and intrapersonal intelligences; (g) self-perception of musical intelligence correlated positively with perceived levels of experience in word-processing, spreadsheets, publishing software, databases, and presentation software; (h) although probably meaningless, self-perception of programming experience correlated negatively with perception of bodily intelligence; (i) computer ownership correlated negatively with perception of mathematical-logical, intrapersonal, and spatial intelligence; and (j) completion of an art course or workshop correlated positively with self-perception of mathematical-logical and intrapersonal intelligence.

Research Question Four

Research question four was: How do the ACT / SAT scores of computer science majors correlate with: (a) field-dependence / field-independence; (b) spatial orientation; (c) spatial scanning; (d) visualization; and (e) self-perception of intelligences? The sample size for these correlations (Figure 5) was 13 as two CS-majors were not required to take the ACT or the SAT.

Figure 5

Correlations of ACT/SAT English and Mathematics Scores with Measures and Perception of Intelligences



Significance of correlations are given at end of bars.

The ACT mathematics score had positive significant correlations (Figure 5) with the measure for visualization and the perception of mathematical-logical intelligence. The mathematics score approached positive significance with the measure for spatial orientation. The highest correlation of the ACT / SAT scores was the English score which correlated positively and significantly with the GEFT. The English score had significant negative correlations with the spatial scanning measure and the perception of interpersonal intelligence.

Since earlier results indicated that advanced CS-majors performed significantly better on the visualization measure and the GEFT while less advanced CS-majors performed better although non-significantly on the spatial scanning and spatial orientation measures, it is questionable if the ACT / SAT scores have as much validity as students progress through college.

The answers to research question four were: (a) the ACT / SAT mathematics measure correlated positively and significantly with the visualization measure and the perception of mathematical-logical intelligence; and (b) the English measure correlated positively with the GEFT and negatively with the spatial scanning measure and perception of interpersonal intelligence.

Chapter 5

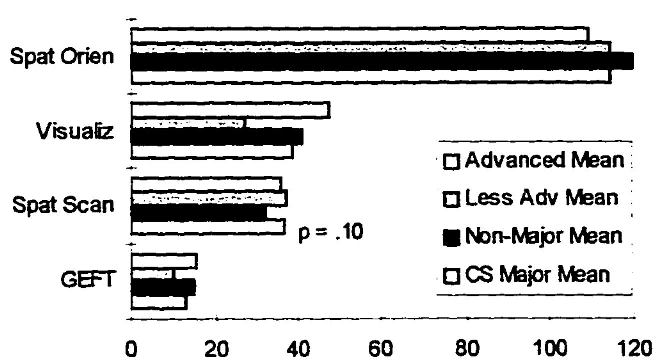
Discussion

The results of this study seem to indicate that spatial measures are not significantly different in CS-majors and in non-CS-majors. However, there are some interesting differences between the two groups; these differences may lead to more questions than answers.

Although non-significant (Figure 6, Table 9), non-CS-majors scored higher than CS-majors on the visualization measure, and advanced CS-majors scored significantly higher than less advanced CS-majors. For non-CS-majors, the range of scores (obtained by subtracting one-fourth the number of wrong answers from the number of right answers) was 13 - 60 (mean = 38.6); for all CS-majors, the range of scores was -3.75 - 57.75 (mean = 38.63); for advanced CS-majors, the range was 35 - 57.75 (mean = 47.61); and for less advanced CS-majors, the range was -3.75 - 52.5 (mean = 27.07). When comparing

Figure 6

Means of Majors, Non-Majors, Advanced Majors and Less Advanced Majors on Measures



individual scores, three less advanced CS-majors scored lower than all other students and two scored above 50. For whatever reason, the three students who scored very low were the ones that biased the data. It is possible that they did not understand the directions or could not then imagine a three-dimensional figure unfolded. Based on my observations, I felt the three students viewed taking the tests seriously. Comparison of the means of the three groups would yield a ranking of advanced CS-majors, non-CS-majors, and less advanced CS-majors.

Table 9

Means of Majors, Non-Majors, Advanced Majors, and Less Advanced Majors on Measures

Measure	Advanced CS-Majors	Less Adv. CS-Majors	Non CS-Majors	All CS-Majors
Spat Orien	108.86	114.14	119.60	114.07[3]
Visualization	47.61	27.07	40.97	38.63
Spat Scan	35.29	37.14	31.80	36.47
GEFT	15.14	10.29	14.67	13.07

Among CS-majors, the year in school correlated positively and significantly with the visualization measure ($r = 0.52$); however, among non-CS-majors, the level of significance was the same as for CS-majors, but the correlation ($r = -0.55$) was negative (Figure 7). A possible explanation is that among non-CS-majors, students in the first and second year had completed more mathematics courses, including calculus, than those in the last two years. Since three-dimensional figures are taught in most second semester calculus courses, the three less advanced CS-majors had not completed the second calculus course while the majority of advanced CS-majors and the two less advanced CS-majors who scored high on the measure had completed the course, completion of the second calculus course may have contributed most to this statistic.

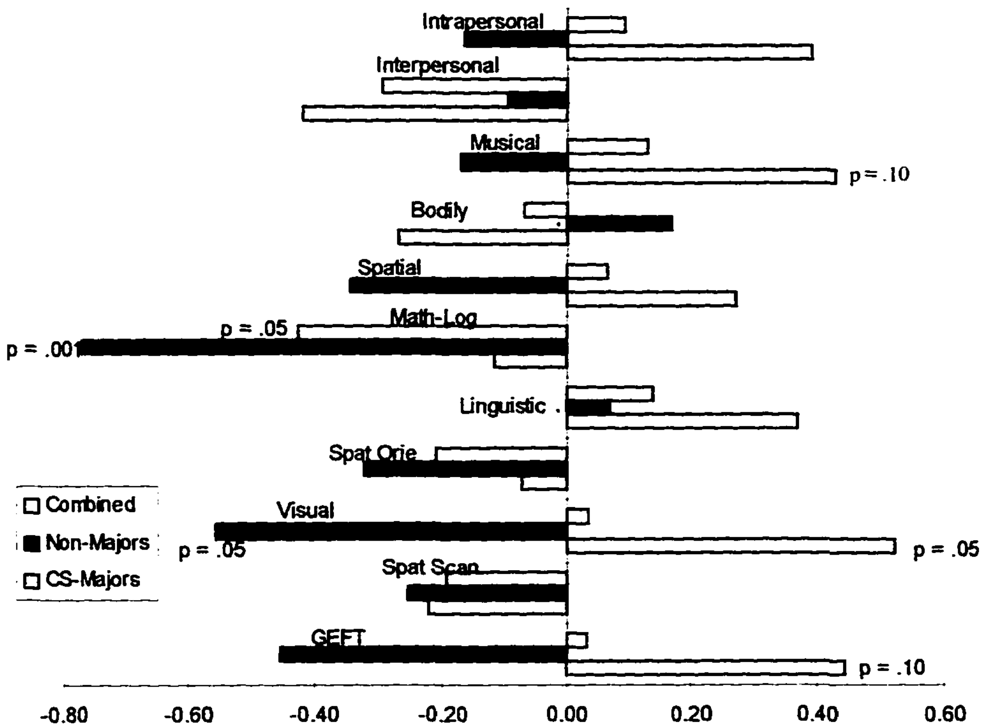
Although non-significant (Figure 6, Table 9), non-CS-majors (mean = 14.7) scored higher overall on the GEFT than CS-majors (mean = 13.07); however, advanced CS-majors (mean = 15.1) scored significantly higher than did less advanced CS-majors

[3]The mean for all CS-majors includes one student who was eliminated from comparisons between majors (see page 55).

(mean = 10.3). Ranking of the three groups by means yields the same results as the visualization ranking. The year in school with the GEFT correlated significantly and at the same level among CS-majors (r = .44) and non-CS-majors (r = -0.46); the difference was that it correlated positively among CS-majors and negatively among non-CS-majors.

Figure 7

Correlations of Year in School with Measures and Perception of Intelligences among CS-Majors, Non-CS-Majors, and Combined Groups



Significance of Correlations are given at end of bars

According to the literature, field independence increases between the ages of eight and 15 and levels off until after the age of 24 when it begins to decline (Witkin et al., 1971); however, adult learners are more field independent and this seems to increase with the amount of formal education (Jonassen and Grabowski, 1993). The GEFT requires breaking the whole apart (Witkin et al.); computer programming also requires one to break the whole into manageable units (procedures or objects). It may be that experience in computer programming is one type of formal education that contributes to field independence.

The results of the GEFT and the visualization measure were almost identical. There was a significant correlation (r = .44) between the GEFT and visualization measure among CS-majors. This correlation was not significant (r = .34) among non-CS-majors

Table 10

Correlations Among Measures With Different Groups

Measure	GEFT	Spat. Scan.	Visualization	Spat. Orien.
CS-Majors				
Spat. Scan	-.32	1.00	-.05	.15
Visualization	.44***	-.05	1.00	.49***
Spat. Orien.	.17	.15	.49***	1.00
Non-CS-Majors				
Spat. Scan	.41	1.00	.57**	.30
Visualization	.34	.57**	1.00	.15
Spat. Orien.	.64*	.30	.15	1.00
Combined				
Spat. Scan	-.03	1.00	.22	.20
Visualization	.41**	.22	1.00	.33***
Spat. Orien.	.38***	.20	.33***	1.00

*p < .01. **p < .05. ***p < .10.

although it was significant (r = .41) among all students (Figure 7, Table 10). The GEFT requires finding a simple shape embedded in a complex shape. The Surface Development Test (visualization measure) presents a two-dimensional drawing with dotted lines indicating folds; to the right of this drawing is a three-dimensional drawing showing the result of folding. Matching the folds with the dotted lines is the goal of the test. The visual test requires that a figure be mentally restructured into components for manipulation (Ekstrom et al.,1995) while the GEFT requires the ability to separate the parts of a field from the whole (Witkin et al., 1971). Consequently, results of this study indicate a relationship between the ability to restructure components and the ability to separate the parts from the whole.

CS-majors (mean = 36.47) scored significantly higher on the spatial scanning measure (Maze Tracing Speed Test) than non-CS-majors (mean = 31.8). This was the only measure (Figure 6, Table 9) that CS-majors scored higher on, either significantly or non-significantly, than non-CS-majors. This factor has been interpreted as a planning function (Ekstrom et al., 1995) and requires addressing of sensory buffers to make a visual search for the path (Carroll, 1974). In its own domain, this ability is similar to that required in rapidly scanning a printed page for comprehension (Ekstrom, et al.). If this is similar to rapidly scanning a printed page, the results would seem to imply that CS-majors have learned to scan better than non-CS-majors. This result would make sense as students often scan computer screens rapidly while looking for specific information. Among both CS-majors and non-CS-majors, the year in school and this measure showed a slightly negative non-significant correlation (Figure 7).

On the spatial orientation measure (Card Rotations Test), non-CS-majors scored higher (mean = 119.6), but not significantly, than CS-majors (mean = 114.07).; however, less advanced CS-majors (mean = 114.14) scored higher than advanced CS-majors (mean = 108.86), also non-significantly (Figure 6, Table 9). The year in school correlation (Figure 7) with this measure approached zero among CS-majors ($r = -.07$); however, among non-CS-majors ($r = -.32$), it approached negative significance. On this test, a two-dimensional shape is presented on the left with the same shape to the right in several different orientations; some have been only rotated, and some have been turned over. The student is to determine which has been only rotated and which has been turned over. This measure correlated positively and significantly with the visualization measure (Table 10) among CS-majors , positively and non-significantly among non-CS-majors, positively and significantly among all students. There seems to be some difficultly in explaining the differences between visualization and spatial orientation (Ekstrom et al., 1995). The results of this study did indicate differences in the two among the groups when comparing means (Figure 6, Table 9). On the visualization measure, advanced CS-majors had the highest mean, followed by non-CS-majors, and last was less advanced CS-majors. On the spatial orientation measure, non-CS-majors had the highest mean, followed by less advanced CS-majors, and last was advanced CS-majors. It has been hypothesized that the figure is perceived as a whole in spatial orientation while restructuring of components for manipulation is required in visualization (Ekstrom et al.). If this hypothesis is correct, this group of advanced CS-majors would indicate that experience in computer programming increases ones' ability to restructure components and decreases ones' ability to perceive the figure as a whole. Computer programming is taught with both an object-oriented and a procedural approach. When using an object-oriented approach, one thinks in terms of what each object contributes to the whole; when using a procedural approach, one thinks in terms of the small pieces making up the whole. In either case, the emphasis is on the components which makeup the whole. Thus, it may be that experience in computer programming does increase the ability to restructure components (visualization) and decrease the ability to perceive the figure as a whole (spatial orientation).

On first observation, what appeared to be a disturbing result occurred between year in school and perception of mathematical-logical intelligence (Figure 7). Among majors, this correlation was slightly negative ($r = -.12$); among non-majors, the correlation ($r = -.77$) was negative and significant at the 0.001 level; among all students, this correlation ($r = -.42$) was negative and significant at the 0.05 level. However, among all groups, completion of College Algebra correlated positively and significantly with perceived mathematical-logical intelligence. Completion of Calculus 1 and Calculus 2 also exhibited positive correlations although not always significant. No non-majors had taken any advanced math course. Total math courses completed (calculated by number of boxes checked on the questionnaire) correlated with mathematical-logical intelligence among both CS-majors and non-CS-majors at a significance level of 0.05 and among all students at a level of 0.001. At first, the implication seemed to be as students progressed through college, their perception of mathematical-logical intelligence decreased. A different approach to the data revealed that the average number of math classes completed by freshmen and sophomores was 5.3 while upperclassmen had completed only 3.7 math classes; although this average was for combined groups, it was consistent across groups. Thus, it may be the number of math classes completed has more impact on the perception of mathematical-logical intelligence than the year in college. This result seems plausible for CS-majors as junior and senior CS-majors were not required to take as many math classes as freshmen and sophomore CS-majors due to the program change. For non-CS-majors, it may be that those who wait until their junior or senior year to take statistics have fewer math skills than those who take statistics during their first two years.

Since advanced CS-majors perceived a significantly higher level of intrapersonal intelligence and the only intelligence that less advanced CS-majors perceived more of was interpersonal intelligence, it may be that the questionnaire for perception of intelligences unintentionally forces one to favor one of the personal intelligences. Other reasons may be that the less advanced CS-majors are more socially oriented, that the maturity of advanced CS-majors has increased their intrapersonal intelligence and decreased their interpersonal intelligence, or all can be attributed to the difference in personalities of the two groups.

Summary

Research question one examined differences in CS-majors and non-CS-majors. CS-majors scored significantly higher on the spatial scanning measure while non-CS-majors scored higher, approaching significance, on the GEFT. Although not approaching significance, non-CS-majors also scored higher on the visualization and spatial orientation measures than did CS-majors. Non-CS-majors had a significantly higher self-perception of linguistic intelligence than did CS-majors.

Research question two examined differences in advanced and less advanced CS-majors. Advanced majors are significantly more field independent and scored significantly higher on the visualization measure than less advanced majors. Although non-significant, less advanced CS-majors scored higher on both spatial measures than did advanced CS-majors.

When the results of the first two questions are linked, they become much more interesting. Ranking of the three groups (non-majors, advanced majors, and less advanced majors) on the measures resembles a queue where the front object reenters the queue at the rear for the next measure. If N represents non-CS-majors, A represents advanced CS-majors, and L represents less advanced CS-majors, the order on the GEFT and the visualization measure is ANL; on the spatial orientation measure, it is NLA; and on the spatial scanning measure, it is LAN. When viewed from this perspective, spatial orientation is the only measure that non-CS-majors scored higher on than either group of CS-majors. Two advanced CS-majors found the right shape in the right size but in the wrong orientation on the GEFT, and, overall, advanced majors did worse on the spatial orientation measure. Working with objects on a computer monitor allows one to rotate, flip, and find mirror images easily. Although the shape and size of the object are preserved, the direction or orientation of the object is altered. It is possible that this experience allows students to see the same object regardless of its orientation.

Research question three considered correlations among CS-majors. The most significant correlations existed with perception of musical intelligence which correlated with six of the eight different computer experiences, year in school, and size of high school. Perception of mathematical-logical intelligence correlated positively with completion of various mathematics classes and an art course or work shop and negatively with computer ownership. However, the most disturbing correlations were with the year in school especially when non-CS-majors and all students were considered. As Figure 7 illustrates, there are many more correlations on the negative side than on the positive side. Perception of linguistic intelligence is the only one that is consistently positive. The perception of interpersonal and mathematical-logical intelligence is consistently negative. The mathematical-logical may be explainable as freshman and sophomore students had completed more mathematics classes than junior and senior students. The decline in perception of interpersonal intelligence as students progress through college is troublesome, especially since that is a skill that employers consider valuable in an employee. It is possible that the questionnaire for measuring intelligences is not valid for this age group or it may be the particular group of students used in the study. Both spatial measures show consistently negative scores although the perception of spatial intelligence is positive for CS-majors and all students. It may be that students who take statistics in their first or second year have more skills than those who wait until their last two years to take statistics; however, some of the waiting has to be attributed to when it fits into a schedule. If it is not the particular group of students in the study, then we need to examine our methods and what we are teaching undergraduate students to find out what causes the decline in all these measures as students progress through college. The year in school with the visualization and the GEFT measurements show nearly equal positive correlations for CS-majors and negative correlations for non-CS-majors. Whether or not this can be attributed to completion of computer science classes cannot be determined by the data collected since it could be differences in the students.

Research question four compared ACT / SAT mathematics and English scores with the various measures. Some of the CS-majors had participated in all three studies. Since earlier studies showed more and higher correlations with the mathematics measure in particular, the question of how much validity the ACT / SAT measurements have as students progress through college arises. Considering the different courses and exposure to different ideas and cultures that students experience, it may be possible that while ACT / SAT scores are a good indicator of success in college, they become less valid for comparison purposes as students progress through college.

Whether or not computer programming is a science, an art, or both was not conclusively determined by this study. There are significant differences in advanced CS-majors, less advanced CS-majors, and non-CS-majors. However, some of these differences must be attributed to the particular samples; whether or not some can be ascribed to the way computer science courses influence the intelligences cannot be determined by the data.

Educational Implications of the Research

Previous studies (McCoy and Orey, 1987; McCoy and Dodl, 1989; Reed et al., 1988; Palumbo and Reed, 1991; Reed and Palumbo, 1992) have shown that experience in computer programming improves problem-solving ability. If the results of this study can be replicated, computer programming experience may also improve some visualization skills, albeit, the experience may also cause a decline in some spatial skills.

Visual and spatial skills have been shown to be important in navigating hypermedia systems (Vicente et al., 1987; Butler, 1990; Norman and Butler, 1989; Lidwell et al., 1994). Since several of the intelligences have been shown to develop at an early age (Begley, 1996), it may be that we need to teach more visual / spatial skills at an early age. Activities such as mazes, finding differences in pictures, and finding the object that is the different or same in a group are often considered fun by children who are developing visual / spatial skills as they perform the activity.

The year in school correlation with different measurements and perception of intelligences should be closely examined. If similar results are found in different groups, than educators need to examine their methods and content to discern what causes the decline in the various categories as undergraduate students progress through college.

Suggestions for Further Research

It seems that using the same students as they progress through college in various majors for the different intelligences would allow a valid comparison to discern which of the intelligences are influenced by particular courses and / or majors. Using different students does not account for differences that already exist in the students.

Since the visualization measure and the GEFT showed nearly identical results, the GEFT could be compared to the same or other visualization measures with other groups. Whether or not the results of this study can be replicated is of interest in predicting relationships between field dependence / independence and visualization ability.

Since many of the intelligences have been shown to develop at an early age, it is possible that the intelligences are influenced by classes in elementary, middle, and high school. Studies of the influence of different courses on the various intelligences at an earlier age would contribute valuable information to the field.

It is possible that the tests used are not measuring the intelligence accurately or that the questionnaire used was not valid for college students. Gardner (1991) suggests that most objective tests are designed for statistical precision; as such, they may not provide a good sampling of the skills and understandings that one wants students to acquire.

Finally, the sample size of 15 CS-majors and non-CS-majors, and seven advanced and less advanced CS-majors may be too small to give valid results. The use of larger samples for all three groups might yield different results.

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Appendix A

Personal Data

Name: ____________________________________ Date: ___________________

Year in College: ______________ Age: _____________ Sex: __________

Major Area of Study: ______________________________

Circle the approximate number of students in your high school:

Under 500, 500 - 750, 751- 1000, Over 1000

Circle the math courses that you have completed:

Algebra I Algebra II / College Algebra Geometry Calculus I

Calculus II Statistics Math Courses above Calculus II

On a scale of 0 - 5, (0 = no experience .... 5 = very experienced), rank your ability with the following types of computer applications:

word-processing __________ database applications __________

spreadsheet applications __________ drawing programs __________

game-playing __________ programming __________

publishing applications __________ presentation applications __________

How many programming languages do you know? __________

Do you own your own computer? __________

Have you taken any type of art course or attended any art workshop? __________

Appendix B

Script for Study

Good Morning (afternoon, evening). Thank you for agreeing to participate in my study. The goal of my research is to study mathematical-logical and spatial intelligence, as well as field dependent / independent learning styles and their relationship in the general college student and the computer science student. The information gathered will be used for my doctoral dissertation.

I want to point out several thing to you before we start:

1. Your participation is entirely voluntary and you do not have to respond to every item or question;

2. Your responses will remain anonymous and confidentiality will be maintained;

3. Neither your class standing, athletic status, or grades will be affected by refusing to participate or by withdrawing from the study.

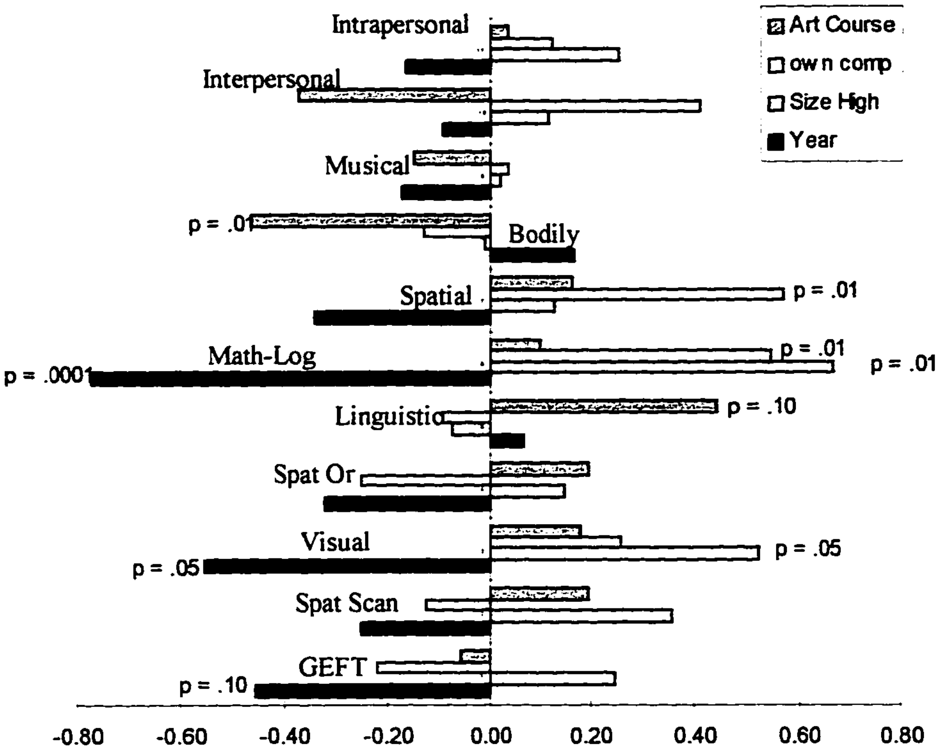
Thank you for agreeing to participate in this study.

Appendix C

Correlations Among Non-Majors

Figure C1

Correlations of Year in College, High School Size, Computer Ownership, and Completion of Art Course among Non-CS-Majors



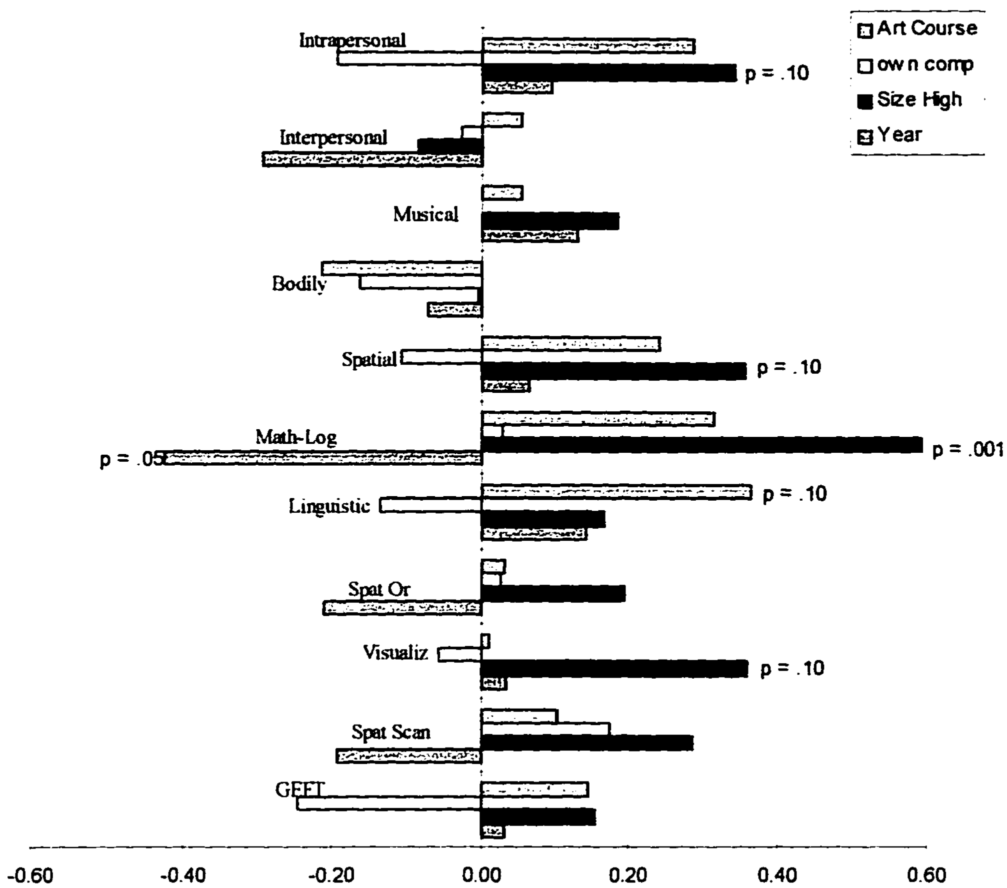
Significance of correlations are given at end of bars.

Appendix D

Correlations Among Combined Groups

Figure D1

Correlations of Year in College, High School size, Computer Ownership, and Completion of Art Course among Combined Groups



Significance of correlations are given at end of bars.

ABSTRACT

The purpose of this study was to determine if spatial intelligence contributes to a student's success in a computer science major or if mathematical-logical intelligence is sufficient data on which to base a prediction of success.

The study was performed at a small university. The sample consisted of 15 computer science (CS) majors, enrolled in a computer science class, and 15 non-CS-majors, enrolled in a statistics class. Seven of the CS-majors were considered advanced and seven were considered less advanced.

The independent measures were: the mathematics and the English scores from the ACT / SAT (CS-majors); a questionnaire to obtain personal information; the major area of study which compared CS-majors to all other majors; and the number of completed computer science classes (CS-majors) to determine advanced and less advanced CS-majors.

The dependent measures were: a multiple intelligence inventory for adults to determine perception of intelligences; the GEFT to determine field independence / dependence; the Card Rotations Test to determine spatial orientation ability; the Maze Tracing Speed Test to determine spatial scanning ability; and the Surface Development test to determine visualization ability.

The visualization measure correlated positively and significantly with the GEFT. The year in college correlated positively and significantly with the GEFT and visualization measure for CS-majors and correlated negatively for non-CS-majors. Although non-CS-majors scored higher on the spatial orientation measure, CS-majors scored significantly higher on the spatial scanning measure. The year in college correlated negatively with many of the measures and perceptions of intelligences among both groups; however, there were more significant negative correlations among non-CS-majors.

Results indicated that experience in computer programming may increase field independence, visualization ability, and spatial scanning ability while decreasing spatial

orientation ability. The year in college had a positive correlation with only the perception of linguistic intelligence among all groups; it had a negative correlation with all other perceptions of intelligences and measures in at least one of the groups. Although significant differences existed between non-CS-majors and CS-majors, and between advanced and less advanced CS-majors, whether computer programming is a science, an art, or both was not conclusively determined by this study.

APPROVAL OF EXAMINING COMMITTEE

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7/11/97
Date