The Dissertation Committee for Gloria Aileen Brown Wright certifies that this is the approved version of the following dissertation:

Effects of Using Presentation Formats That Accommodate the Learner's Multiple Intelligences on the Learning of Freshman College Chemistry Concepts

Committee:

____
Joseph J. Lagowski, Supervisor

____
Richard A. Jones

____
Kent K. Stewart

____
Marilla D. Svinicki

____
John M. White

Effects of Using Presentation Formats That Accommodate the Learner's Multiple Intelligences on the Learning of Freshman College Chemistry Concepts

by

Gloria Aileen Brown Wright, B.A., M.S.

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Dedication

To my dearest daughter, Karla Loreen, God's special gift to me.

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Howard Gardner's Theory of Multiple Intelligences identifies linguistic, spatial and logical-mathematical intelligences as necessary for learning in the physical sciences. He has identified nine intelligences which all persons possess to varying degrees, and says that learning is most effective when learners receive information in formats that correspond to their intelligence strengths. This research investigated the importance of the multiple intelligences of students in first-year college chemistry to the learning of chemistry concepts. At three pre-selected intervals during the first-semester course each participant received a tutorial on a chemistry topic, each time in a format corresponding to a different one of the three intelligences, just before the concept was introduced by the class lecturer. At the end of the experiment all subjects had experienced each of the three topics once and each format once, after which they were administered a validated instrument to measure their relative strengths in these three intelligences. The difference between a pre- and post-tutorial quiz administered on each occasion was used as a measure of learning. Most subjects were found to have similar strengths in the three intelligences and to benefit from the tutorials regardless of format. Where a difference in the extent of benefit occurred the difference was related to the chemistry concept. Data which indicate that students' preferences support these findings are also included and recommendations for extending this research to other intelligences are made.

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Introduction

STATEMENT OF THE PROBLEM

The Clientele of College Chemistry

Each semester, the Department of Chemistry and Biochemistry at the University of Texas, as do universities and colleges all over the United States and around the world, enrolls large numbers of students in first-year chemistry courses. The greatest portion, by far, of these students are non-majors who are taking a chemistry course because it is required by their disciplines (1). They represent science and science-related disciplines such as biology (2) and engineering (3), as well as other nonscience majors (4, 5).

In the past, a large number of the students found in today's college chemistry classrooms would not have been given the opportunity to study chemistry. Due, in part, to sub-standard high school preparation in mathematics and chemistry (6, 7) they arrive at college with varying levels of unpreparedness for the demands of first-year college chemistry. Various reasons for this level of preparedness exist. Alternative conceptions (5, 8) which are sometimes resistant to change have been identified as among the factors which impede students' learning of accepted chemistry concepts. Being married (9) and being first-generation college students (10) have been added to the list of societal factors found to have negative effects on success in college.

Enrolled in chemistry courses, such students present a challenge both to chemistry departments, which must invest additional efforts to help them achieve success, and to chemistry instructors who must find appropriate ways to address different learning needs (11, 12).

Gabel (13) projects that this trend will increase rather than diminish, and that in the new century classrooms will be more diversified, international and heterogeneous in terms of students' backgrounds. It is therefore imperative that chemistry educators develop the necessary awareness and skills so as to optimize the likelihood of meeting this inevitable challenge with success.

The College Chemistry Classroom

A pivotal component of the problem is the chemistry classroom. In this learning milieu concepts have traditionally been conveyed, for the most part, via linguistic and mathematical formats. This is not surprising, given the finding that high mathematics scores and success in chemistry tend to go together (14, 15) and the pervasive assumption on the part of education practitioners that there is basically one way of teaching a subject and one way of learning it, and that success in that milieu indicates intelligence. Unfortunately, the majority of the general population is linguistically and mathematically challenged (16), and instructors in higher education do not always realize that students vary in the way they process and understand information.

THE SEARCH FOR SOLUTIONS

Traditional Approaches

This challenging situation, although escalated in recent years, is by no means new to college chemistry (17) or to college education in general (18). The very first volume of the Journal of Chemical Education (19) carried an article which described extensive testing of students coming in from high school, in order to measure their preparedness for college chemistry. General intelligence tests were supplemented by specially developed placement tests (20, 21) which included chemistry as well as mathematics items, but even these were found to be limited in their ability to make accurate predictions of student achievement in chemistry (22). Wolf (23) compared one general intelligence predictor and four chemistry-based predictors and concluded that performance on the general intelligence test should not be used as a basis of excluding a student from studying chemistry, although it may be used to guide the student toward a less demanding course. Ozsogomonyan and Loftus (24) concluded that placement tests were of uncertain value as predictors of success in first-year college chemistry.

The uncertainty in how best to determine a student's readiness for college chemistry is part of the larger uncertainty about how to evaluate preparedness. Yet, the influx of non-traditional chemistry students has given added urgency to the screening of students through course pre-requisites. Mathematics-based tests may be seen as a way to "quickly and painlessly identify students at risk in college-level chemistry" (25). Among the commonly used cognitive instruments are the Toledo Exam, the California Diagnostic Test, the Math SAT, the GALT and the ACT (6, 25, 26). Wagner et al (6) found that a pre-course instrument that assessed both mathematics and chemistry knowledge was a better predictor of success in first-year college chemistry than the Toledo Exam or the MSAT. The ACS Examinations Institute, now located at the University of Wisconsin-Milwaukee (27, 28) has available placement tests for several levels of chemistry. Both chemistry- and mathematics-based placement tests continue to be used to screen students for college chemistry (6, 14, 15). In some cases the results are used as a basis of providing supplemental tutoring for under-prepared students (29, 30). Yet there are some students who qualify for college chemistry on the basis of this screening process but do poorly in the course (24).

Student-centered Approaches

Increasingly, educators are recognizing that attention to other than content is required for effective teaching of the diverse students in their charge, and through various approaches they are now actively engaged in seeking to understand individual student differences in order to arrive at more appropriate and effective pedagogical practices (31). Traditional approaches to solving the problem of under-prepared students in chemistry have focused on adapting the student to fit the discipline. However, several studies indicate differences in the way people process the same information (11, 12, 13) and research suggests that presenting information in formats that are sensitive to the way people process information can contribute to effective learning (32, 33). .Some learners' working styles are independent of content whereas others' are a function of the subject matter. Learning occurs when instructors affirm the presence and validity of diverse learning patterns and maximize the climate and conditions for learning, taking into account learning differences, and thus increasing the possibility of success for all learners.

One model that has been proposed for increasing learning opportunities is the theory of multiple intelligences. In the early 1980s Howard Gardner (16), a researcher in neuropsychology at Harvard University, proposed a way of looking at learning that has been described as among the most significant developments on the educational scene in the last fifty years (34). The attractiveness of the theory has been ascribed to the fact that it is learner-centered, accommodates many types of individual and socio-economic diversities found among learners, and counters the tradition of relying on standardized tests. Like the learning theories that preceded it, the implication of Gardner's theory for the educational process is diversification with a view to including all learners.

Gardner agrees with cognitive psychologists that learners differ in how they learn, and that for effective learning to occur these differences need to be accommodated. Gardner's Theory of Multiple Intelligences proposes, however, that individuals possess several intelligences which they can access, as needed, when faced with a learning situation. The intelligences are not preferences, as are learning styles, but are ways that people learn, and everyone possesses them all, though to varying extents (35).

Gardner says that specific disciplines are facilitated by specific intelligences, and he identifies three intelligences as central to learning in the physical sciences: logical-mathematical, spatial, and linguistic. Learning, he says, is most effective when the learner's intelligence strengths coincide with the intelligences required by the discipline. This model then provides a theoretical basis for designing effective instruction in physical sciences such as chemistry. Specifically, the model proposes that when individual differences in multiple intelligences are taken into account in the way concepts are presented, learning will be enhanced.

The present study is a test of this hypothesis in the discipline of chemistry. Specifically, this study proposes to test the effect on learning when chemistry concepts are presented in formats that coincide with the learner's intelligence strengths. If the theory of multiple intelligences is a useful model, there should be identifiable differences among chemistry students in the strength of various intelligences, and when students are working with materials designed to be compatible with their intelligence strengths they should show greater learning gains than when the format of presentation is reflective of another intelligence. Stated as testable hypotheses, this study is evaluating the following assertions:

NULL HYPOTHESES

In the context of Howard Gardner's Theory of Multiple Intelligences this experiment sought to investigate the following null hypotheses:

1. First-semester college chemistry students cannot be distinguished as being high in either linguistic or spatial or logical-mathematical intelligence.
2. The extent of learning of first-year college chemistry concepts does not vary with the format used to present the concepts.
3. The learners' multiple intelligences do not determine the extent of learning from a presentation format in first-semester college chemistry.
4. In first-semester college chemistry the learners' primary intelligence does not coincide with the format that produces optimal learning.

CHAPTER II

Literature Review

THE NATURE OF CHEMISTRY

There are several studies that explore the nature of abilities that contribute to learning chemistry. Abilities in logical-mathematical thinking and linguistic proficiency, well as the ability to visualize spatial relationships, seem to be key to achieving in chemistry.

Logical and Mathematical

The mathematical nature of chemistry has long been recognized and its importance emphasized in the learning of chemistry concepts (25, 26). The tests given to determine students' readiness for first-year college chemistry measure logical and mathematical thinking (17, 36) and the remedies put in place are wholly mathematical or have a strong mathematical component (6, 29). For the most part, chemistry educators have been satisfied with the ability of mathematics-based evaluation to predict success in first-year college chemistry.

Linguistic

Along with logical and mathematical skills, the ability to read and comprehend is also considered prerequisite to success in a college chemistry course. This goes without saying, since the student must access the course information primarily by listening in class and reading words in the textbook, then submit to assessment processes which also require them to read and understand sentences in order to respond. In some cases (25) scores on the verbal SAT test are included in the assessment, but even where this is not the case, mathematics-based placement tests are indirectly a measure of language proficiency. Mbamalu (12) identifies language difficulty as one cause for failure in the sciences. Many of the words the student encounters in chemistry may seem familiar but they have very specialized and sometimes abstract meanings (13) and it is important that the student learn their precise meanings and how to use them correctly in the context of chemistry. Even when students learn the meaning of these words they also need to understand the concepts that are described by these words. Williamson et al. (37) found that after learning the particulate theory, some students who recognized the vocabulary of particulate theory in a question incorrectly used it as clues and answered in terms of the particulate theory when the questions did not require it. Inability to cope with the language required to master the laws and relationships of science often results in the student becoming frustrated, losing interest, and dropping out (12). To be successful in chemistry the student must learn this new language, and so efforts to help under-prepared students succeed in science must also include help with vocabulary acquisition.

Spatial

Chemistry, in common with other physical sciences, utilizes logical-mathematical and linguistic media as vehicles of expression. However, in chemistry there is an additional medium that is highly important but tends to be neglected – the spatial (36, 38). This involves using the physical eye to make observations which are appropriately interpreted and mentally stored for use by the "mind's eye" (visualization) and also the ability to relate to the results of their movements in space (orientation) (39). Zare (40) describes chemists as "highly visual people" who "see" molecules and visualize them and the transformations they undergo. For example, when chemists draw a structure on a two-dimensional surface they see it in three dimensions.

Barke and Engida (36) studied the spatial abilities of school children in Germany and Ethiopia and concluded that spatial ability developed in response to cultural factors but that the greatest determinants were the demands of the school curriculum. They recommend grade 8 as the optimal time to introduce structural models. This, they say, will lead to better understanding of concepts which require spatial ability. Other researchers concur that the beginning chemistry student must be deliberately initiated into these and other conventions of representation that are second nature to the expert chemist, and that the chemistry course should provide these opportunities (38, 39). Failure to consciously and deliberately make this an objective of introductory chemistry courses has resulted in limited spatial skills and has hampered learning in chemistry (41). Both static (42) and animated (43) visualizations have been reported to improve students' understanding of chemistry concepts.

Chemical bonding is an example of a concept that extensively uses spatial models, whether they be drawings on paper of single and multiple bonds, physical molecular models which can be purchased, or computer-generated representations of mathematical models. Bonding theories require students to interpret observations that cannot be directly experienced, a process they find difficult (41). For chemists, a graph is a meaningful translation of a mathematical model into a spatial model but many students are slow at making the mental transition. A non-mathematical pictorial approach recommended by Miller and Verkade (44) for visualizing bonds via the highly mathematical molecular orbital concept theory could serve as a useful learning tool for teaching visualization in chemistry. Similarly, Lang and Towns (45) report great success in helping students bridge the gap between the concrete picture of atomic structure that classical mechanics present and the abstract concept derived from quantum mechanics by using a mathematics-based computer program which generates graphs of atomic wave functions and their probability densities.

Chemistry on Three Levels

The learning of chemistry is complex, requiring interaction with concepts on microscopic, macroscopic and symbolic levels (13, 46) that involve mathematical, linguistic and spatial conceptualizations. As needed by the problem under consideration, the chemist visualizes spatially, calculates mathematically and describes linguistically the property of the substance of interest at the microscopic level as subatomic particles, at the symbolic level by a chemical formula, or at the macroscopic level as a sample of matter. Observations in chemistry are made at the concrete macroscopic level but explanations are made at the microscopic level using abstract language and expert chemists routinely think at all three levels, separately or in any combinations, and easily switch between them even without consciously making the transitions. College students were found to have great difficulty making the transitions and connecting the three levels, and often could not make sense of the explanations (13). Sanger observed that, when presented with microscopic representations of substances, some students utilized visual cues but misapplied macroscopic definitions to the microscopic representations; however, those that received prior instruction were more likely to interpret the drawings correctly (47).

Successful learning in chemistry means understanding chemistry at the microscopic, macroscopic and symbolic levels, and therefore presenting chemistry concepts in formats compatible with linguistic, spatial and logical-mathematical intelligences at all three levels could enhance learning in chemistry.

EFFECT OF PRESENTATION FORMAT

Varying the Format

Several of the recent theories about learning are reflected in innovations that have been attempted in chemistry pedagogy. Niaz and Robinson (48) found that students' abilities to solve gas-law problems varied greatly, depending on the approach utilized, even after training or experience. Richard Felder (49) describes a sequence of five experimental courses in chemical engineering that were designed to meet the needs of students with various learning styles. Coleman and Gotch (39) report that a 12-year study of general chemistry students at Southeast Missouri State University indicated that whereas the mean abilities of male and female student did not change over the period of study, there was a general decrease in spatial perceptual skills among males while that of the female students remained approximately steady, on an average. This they interpreted as indicating decreased preparation on the part of those students to engage in formal thinking.

At Columbia College Chicago, Lerman (50) has succeeded in helping nontraditional students learn chemistry, using unconventional methods which downplay linguistic and mathematical abilities. Students expressed chemical concepts visuo-spatially using dance, cartoons and computer graphics. In one project the bombardment of a nucleus was depicted electronically as well as by dance movements choreographed by the students. Many of these inner-city students have gone on to careers in pharmacology, medicine, chemical engineering and chemistry. She reported that one former student chose to enter a Ph.D. program in biochemistry, one had just about completed a doctoral degree in chemistry and another had already received a doctorate in molecular biology.

Francisco, Nicoll and Trautmann (51) as well as Brown Wright (52) found that multiple teaching strategies were well received by general chemistry students, and they not only aided students with unusual learning patterns but were useful in broadening and deepening the understanding of those who do well in the traditional classroom setting, since often such students excel at "rote, repeat and give-back" rather than at true understanding.

It would appear from the above citations that variation in presentation formats provides learners an advantage in learning chemistry. This might arise because a wider spectrum of learners are given the opportunity to access their differing intelligence strengths, a basic tenet of the present study.

Use of Multimedia

Jones and Berger (53) found that undergraduate students are able to use their individual learning styles in a well-designed multimedia chemistry instructional program. The Open University in Britain, with no entrance requirements, (54) has been successful in teaching science to non-traditional students, most of whom are working persons between 25 and 45 years old. They use readily accessible multimedia such as television programs, video and CD-ROM and, to a limited extent, the internet. Practical lessons include experiments that can be done safely at home using easily available items. These are augmented by occasional group tutorials and weeklong summer sessions at university campuses around the country. Most of the students are non-science students, but the experience has inspired several to pursue further studies in an area of science.

In 1973 Sam Castleberry et al (55) of the University of Texas published a report of a successfully-designed chemistry computer-enhanced course which incorporated information on student learning styles and generated individually-tailored remedial modules. At the 1991 NARST conference Nakhleh and Krajcik (56) presented a paper in which they reported that with the aid of technology students' understanding of several chemical concepts improved. Similarly, Williamson and Abraham (43) found that although students indicated no preference when concepts involving the particulate nature of matter were presented in a static or in an animated manner, the animated presentations led to improved performance on questions which tested conceptual understanding, though not on questions which simply required rote or "number-crunching". In chemical engineering multimedia-based instructional materials have been developed at the University of Michigan (57) with the objective of accommodating learning style preferences. Gabel (13) predicts that computers will play an increasingly significant role in these endeavors. Wooldridge (32) encourages pursuing research to determine the effectiveness of using technology to meet the pedagogical needs of different learners. Technology could be used to facilitate the presentation of chemistry concepts in a variety of multiple intelligence formats.

THEORIES OF LEARNING

Over the years, educational psychologists have devised various explanations of how people learn and why some persons and not others are successful in certain learning situations. The various theoretical formulations reflect the concept of learner differences as the basis for differences in achievement and seek to explain the observation that individuals learn differently. They also support the assertion that an important aim of education is to help people fully use their spectrum of capabilities, and that this should be done in a manner that aids each person in maximizing his/her potential. Some theories that are thought to be applicable to college-level learning situations are discussed below. They have in common the objective of broadening the concept of intelligence and justifying the democratization of educational opportunities.

{i} Left-brain right-brain

The idea of "cerebral localization" was first proposed by a German anatomist, Franz Gall and later promoted by Paul Broca, a young Parisian surgeon who became convinced of the asymmetry of the human brain, as a result of several post mortem examinations that he conducted (58). In the early 1970s Roger Sperry (59), a psychologist at the University of California formalized these ideas into a theory that the human brain was differentiated into left and right sides where different modes of thinking occurred. Repeated studies, he maintained, confirmed that the two hemispheres of the brain had different functions. Human brains in which the two halves were separated were able to carry out independent tasks. He proposed that the left side of the brain controlled logical, sequential, rational, analytical and objective thinking whereas the right side of the brain controlled random, intuitive and subjective thinking. Although some persons are adept at using both the left and right sides of their brains, most individuals, he said, had a distinct preference for one style of thinking: left-brain thinking focused on the components of a problem, while right-brain thinking synthesized the components and looked at the whole. The left side of the brain was more active in activities that involved the use of language – oral, written or in reading, for solving mathematical problems and for processing information in a linear sequential manner, whereas and the right side of the brain was more active when listening to music, drawing, daydreaming, absorbing color and graphics, for music and for rhythm.

Some educators believe that traditional education is designed primarily for left-brained people so that, currently, the odds are strongly in favor of those whose learning style is abstract conceptualization. This puts left-brain persons at a definite advantage in the formal educational system (58). A study done by Hunter and McCants (60) in 1977 showed that younger college students preferred a more concrete experiential mode of learning, and studies done by W. Purkiss (61) for a doctoral dissertation at The Claremont Graduate School showed that at the college level previously successful concrete learners are at a disadvantage when compared with previously less successful abstract learners.

Proponents of "whole-brain" learning recommend that the curriculum be redesigned to include learning opportunities requiring the use of the right side of the brain (62). They are concerned that the right brain side of the brain not be seen as a "minor" hemisphere, since it's contribution to intelligence and behavior, though specialized, is important (63).

(ii) Experiential Learning Theory

Building on the ideas of John Dewey, the cognitive psychologist David Kolb in 1971 proposed a theory which describes learning as a process in which adult learners create knowledge through transformation of experience. He saw experience as central and postulated the Experiential Learning Theory (ELT), defining learning as a "process whereby knowledge is created through the transformation of experiences (64).

Reflective of the right brain/left brain theory, he identified "concrete" and "abstract" as two ways of perceiving information that were at opposite ends of a continuum. However, he said, there is also a continuum of ways of processing information – active and passive. By intersecting these two lines of continuum, four quadrants which characterize adult learners are produced: concrete experience, reflective observation, abstract conceptualization, active experimentation (65). McCarthy (62) recommends incorporating this approach as the way to reach all learners.

Kolb and his colleagues (66) believe the educational system is in need of a revolutionary change to make learning, rather than a degree or profession, the focus of post-secondary education. This requires that the learner incorporate new information in a way that is meaningful to her or him. He recommends ELT as an approach that provides the learner with a milieu in which many different ways of learning can flourish and interact, thus promoting self-directed change. The emphasis will not be on the activities carried out by the teacher but on the "value added" to the student.

(iii) Transformative Learning Theory

Wink (67) finds Jack Mezirow's Transformative Learning theory (68) very suited to science pedagogy in that it incorporates non-traditional learning modes such as interpersonal communication. This constructivist theory is similar to Kolb's ELT in emphasizing that adult learning occurs in the context of experience. The desired learning is enhanced or hindered by the meaning attached to the experience. Mezirow says he bases his theory on findings that indicate that people's actions are determined more by how they interpret and explain what happens to them than by the experiences themselves. He says that there is a need for "disorienting dilemmas" which challenge the learner's established ideas and serve as catalysts for critically reflective assessment, leading to the creation of a new reality. Designing the learning situation to include situations that do not conform to preconceptions sets the stage for meaningful learning (69).

(iv) *Learning Styles*

Since the 1960s, several studies on adult learning styles carried out in

Australia, Europe and North America have appeared in various publications. North American researchers have a distinctly different approach (70) and characterize a learning style as a "biologically- and developmentally-imposed set of characteristics that make the same teaching method wonderful for some and terrible for others". Their working definition of learning styles is "the way in which each person absorbs and retains information and/or skills" (71). Research carried out in classroom settings, notably by Dunn and associates whose work cover the spectrum from kindergarten to graduate school, (72, 73, 74) resulted in the popularizing of Learning Style theory.

Several educators who have sought to teach with sensitivity to students' learning styles report improved results. This approach has been used in colleges and universities in teaching a wide range of disciplines, including science; in graduate schools; and in preparing students for various careers such as in business, law and the health-related professions (75). Geary and Sims (76) found that in accounting education diverse teaching approaches were needed since students have diverse learning styles. Similarly, Harrison and Treagust (77) found that conceptual change is most successful when a variety of perspectives are presented.

In reporting on the plethora of learning style inventories that exist, Hickcox (70) points out the difficulty of establishing unequivocally persons' learning styles, one of the compounding factors being the lack of agreement between the North American camp and the European and Australian camp. So as not to be hampered by this reality, the suggestion is to use a variety of formats in presenting information.

All of the above theories seek to individualize the learning experience by accommodating the different ways in which learners process information. Sims and Sims (33) concur that if one approach is used some students will not understand the material. They are supported by Wooldridge (32) who makes reference to previous studies at the post-secondary level, including studies by McCleary and McIntyre (78) and by Carroll, Payne and Ivancevich (79), which relate the effectiveness of a variety of instructional methods to specific learning objectives. By paying attention to models of how individuals learn, teaching that enhances learning can be implemented; failure to do so will result in educational endeavors that fall short of the desired results.

(v) *Multiple Intelligences*

An increasing number of educators are embracing Howard Gardner's theory of multiple intelligences and developing curricula that are inspired by their understanding of its implications (34, 80). They welcome what they see as a shift of focus from test results toward activities that promote learning in students. In fact, Gardner is critical of intelligence tests and rejects the traditionally accepted criteria of intelligence which emphasize logical-mathematical intelligence above all others, and which is the basis of current "intelligence" tests. He rejects the traditional view of intelligence as a single component that is measurable by a single score on a single test and that its distribution among human beings is a natural “bell-shaped” curve. (35). This view of intelligence, he says, is the legacy of early information theorists who were heavily influenced by the development of mathematics and logic at the turn of the twentieth century (81). In contrast to the idea that intelligence is inherited and only a few people have high intelligence, Gardner recognizes multiple intelligences, which are all distributed among the total population (16). Intelligence, he says, is not a state of being but a potential which can be realized to a lesser or greater extent as a consequence of the experiential, cultural and motivational factors that affect a person (35).

MULTIPLE INTELLIGENCES

The Theory

The theory of Multiple Intelligences was proposed by Gardner in 1983. His definition of an intelligence is a set of skills that enables one to resolve genuine problems or difficulties, or to create products that are valued in a society (16). Initially he identified seven relatively autonomous human intelligences (82), or ways through which people learn. These satisfied eight stated criteria (83). He subsequently identified two additional intelligences, one of which is still being decided on (35, 84). According to Gardner, these cognitive capabilities are all present at birth in normal people. Individuals develop natural proclivities to learn via particular “biopsychological potentials” (85) as a result of heredity and early training. Both biological proclivity and cultural nurturing determine the distribution of intelligences in an individual.

Although genetic factors set an upper limit for a particular intellectual potential – which, practically speaking, is seldom approached – it is the experiences gained through a person's culture that determine the extent to which it is realized. Thus, although all persons possess all the intelligences, they are developed to varying degrees in different individuals in response to the needs, values and mores of the society in which the person is nurtured (16).

Gardner developed his theory from a review of knowledge accumulated by a wide spectrum of researchers in genetics, psychology, neurobiology, history and philosophy, international development and anthropology, and synthesized it with his own findings from studies of prodigies, idiots savants, brain-damaged persons, normal children, autistic children, children with learning disabilities, experts and people of diverse cultures. The correlation among psychological tests and the results of skill training led Gardner to conclude that, generally, individuals use different learning approaches for different kinds of information and may make use of several intelligences to solve a particular problem. These information-processing approaches reflect intellectual strengths or natural competencies and are always an interaction between biological proclivities and the opportunities for learning that exists within a culture. The school curriculum, the way of teaching and the kind of life and work options available in a culture should all compliment each other and cater to the broad range of intelligences that exist (16).

According to Gardner, any rich, nourishing topic, any topic worth teaching, can be approached in at least seven different ways that map on to a variety of intelligences (86). He gives examples of how this can be done in science, music and history (85). The more intelligences one is able to use in interacting with a concept, the better one knows it. Where the requisite intelligences are not strong the concepts should be translated into a format that coincides with the learner's intelligence strengths and meaningful learning can still take place. When faced with the opportunity to perform a task via different intelligence routes or when exposed to a multiple intelligence situation, the choice made, and how deeply it is explored, will reflect the learner's intelligence strengths. Persons with low proclivity in requisite directions can be initiated into the relevant knowledge through other intellectual competencies in which they naturally have strengths. The alternative intelligences are then used as introductory vehicles or entry points for learning. The entry points may be presented in the form of appropriate analogies or metaphors, or may be multiple representations of the central ideas, and serve to facilitate the requisite intelligences. In this way, intelligences that are at lower levels of development can be stimulated in the learner (35, 87).

One of the immediate consequences of implementations of Gardner's theory has been the lessened dependence on standardized tests and traditional methods of evaluation (80). The established educational system is skewed toward linguistic and logical-mathematical intelligences and the tests used reflect this imbalance. They tend to obscure the abilities of individuals who are weak in linguistic and logical-mathematical abilities, with the result that such persons may be sidelined (88). Gardner (89) cites Piaget that the basis for all logical-mathematical forms of intelligence is the handling of objects, first physically, later mentally, and recommends that mathematical concept be translating into spatial, linguistic or bodily-kinesthetic medium whenever this is possible in order to assist the learner in conceptualization. Gardner warns, however, that if the concept requires logical-mathematical intelligence the desired learning may not occur if the concept is not finally translated into the learner's logical-mathematical intelligence. (16, 35).

Gardner believes that, compared to other theories, his has the strongest scientific support and is the most useful for the twenty-first century. He describes his theory as empirical and compatible with general intelligence theory, not embracing any single set of values or teaching approach. The intelligences should be seen as descriptive constructs, not prescriptive domains. He is concerned that educators be deliberate about using their knowledge of the intelligence differences among learners to personalize instruction but not to label the learners as being or not being of a particular intelligence. At the same time, high standards must not be compromised and rigorous expectations must be maintained. The theory cannot be an educational end in itself but rather a potentially powerful tool to help in the planning of more effective educational programs and in reaching more learners.

The intelligences should not be trivialized or used to trivialize the curriculum or become ends in themselves. Examples of such misuse of the theory include reducing linguistic intelligence to a mnemonic devise, or labeling as musical intelligence a memory device which merely associates words with a tune; or dividing the lesson into unrelated “intelligence activities”; or unnaturally creating activities related to all or most of the intelligences. Since lesson units cover aspects of a topic which naturally lend themselves to multiple approaches to learning, the unique characteristics of some of the intelligences can appropriately serve on different occasions as different conduits to facilitate the learner in accessing the knowledge. (35, 88).

Howard Gardner makes a clear distinction between learning styles and multiple intelligences. Whereas in the former a learner has a personal preference which is used in approaching every learning situation, in Gardner’s theory the learner has several intelligences and uses the most appropriate one or ones for the content. The concept of multiple intelligences is concerned with the intellect, not the personality, the character or the will; not morality; not constructs such as attention or motivation. It engages in processes which facilitate identifying and solving problems that ultimately are of benefit to the society (16, 35).

The Application

From the above discussion it is clear that the concept of multiple intelligences naturally leads to a concern for "individual-centered" education, where the emphasis is on developing skills for solving problems that are important to the learner's way of life. Yet, Gardner was completely taken by surprise that practicing educators, rather than psychologists, were the ones who showed overwhelming interest in his work. This interest on the part of teachers is understandable since the theory is learning- and learner-centered, promotes diversity and aims to educate the whole person while maintaining the substance, depth and quality of the curriculum (31, 90).

Responding to this interest, Gardner published a collection of papers (85) in which he reports on the application of his theory in some actual situations. The curricula of the schools described are developed after his philosophy that an important aim of education should be to help people fully use their spectrum of intelligences, and it should be done in a manner that aids each person in maximizing his/her potential. Campbell and Campbell (80, 91) describe programs in two elementary schools, two middle schools and two high schools where the curricula were reengineered to accommodate the multiple intelligences of the students. They report that more learning took place, as measured by state-mandated tests as well as by curricular objectives.

Applications at the post-secondary level are not as extensive. Diaz-Lefebvre (92) assessed students in a community college in Arizona and found that students who were strong in linguistic and logical-mathematical intelligences were in the minority, but that these were the intelligences emphasized. He is concerned that such students will resort to memorization and regurgitation as coping mechanisms. In response to this problem, principles of the theory of multiple intelligences were incorporated into an interdisciplinary project (93. Both students and teachers gave positive evaluations of their experiences and felt that more learning took place. At another community college Malm (94) profiled students and faculty members in various career/occupational programs at a community college and found that all the intelligences were represented in all the groups, and that faculty and students in each group showed similarity in high and low intelligences. Both outcomes are consistent with Gardner's view that persons learn best through their intelligence strengths and that specific intelligences are required for efficient learning in particular disciplines. It follows that when the method of transmission of information coincides with the learner's natural competence, educational opportunities and options will be enhanced and each person will be enabled to achieve optimum learning.

Gardner sees the development of curricular approaches tailored for individuals with different intellectual profiles as an area that is posed for progress (85). He says that now that it has been established that learners are not all alike with the same kinds of minds, that they are not points on a continuous bell curve, and that their individual differences determine how they learn, the challenge of the twenty-first century is for educators to find ways to incorporate these differences, making them central to teaching and learning (35).

Multiple Intelligences and Chemistry

The number of chemistry educators seeking to make chemistry accessible to a greater proportion of the students who enroll in their courses is increasing. Some of this effort comes out of a concern about the unsatisfactorily high proportion of students who end up with failing or near failing grades for the course (6). Spencer (14) credits cognitive and classroom research with providing a paradigm shift toward greater sensitivity to the presence in today's chemistry classroom of students who learn in different ways. However, pedagogical reform in chemistry has not kept pace with research (13). Of all science educators, physicists are furthest ahead in making curricular changes to meet the needs of their students (30). Gabel (13) projects that research into how college students of diverse backgrounds, learning patterns and abilities learn will lead to a restructuring of the way chemistry content is presented, and that computers will play a facilitating role in achieving this goal.

The Theory of Multiple Intelligences provides a context which could make it possible to identify the broader spectrum of students found in college chemistry classrooms and cater to a wider variety of learners, some of which need chemistry for their discipline of interest, and others who study chemistry in order to understand chemical principles that apply to everyday life. It deals with cognitive issues of content and disciplines of study whereas Learning Style Theory, for example, revolves around the affective domain, being concerned with thoughts and feelings and how persons perceive and process information (95). The Theory of Multiple Intelligences is dynamic, allowing for growth in all the intelligences, rather than characterizing persons as having certain fixed intelligence characteristics or preferred style of learning, and Gardner promotes the development of all the intelligences in the learner through the use of multiple-format presentations in all disciplines.

The intelligences that Gardner has identified as necessary for learning in the physical sciences are logical-mathematical intelligence, which is the ability to recognize ordered arrays and relate to abstract concerns that are linked to reality only by “a lengthy chain of inference, objective writing, reading and testing”; spatial intelligence, which is the capacity to perceive the visual world accurately, perform transformations and modifications on one’s perceptions and recreate aspects even without relevant physical stimuli; and linguistic intelligence in which the learner must have a minimum of competence (16). However, he promotes the use of multiple intelligences in learning concepts in any discipline, both as a way of enhancing learning for those strong in the requisite intelligences, as well as to help those who do not possess the intelligences at the necessary strengths.

Interest in applying Gardner’s theory to the sciences in general (96) and to chemistry in particular (97) is increasing. Boo (98) gives examples showing how four chemistry concepts commonly taught in high school and college can be presented using several different intelligences. Diaz-Lefebvre (93) indicates that the chemistry teacher at his community college welcomed the opportunity to put aspects of the theory into practice and Sweet (99) reports that when she gave her high school chemistry class opportunity to learn by multiple intelligences, two students who used their kinesthetic and spatial intelligence strengths, respectively, for problem-solving experienced successful mastery of nuclear and organic chemistry concepts. With linguistic and logical-mathematical intelligences already catered for by the educational system, science educators need to make a conscious effort to promote spatial intelligence. Habraken (97) believes that the current dominance of visual media outside of the classroom has imbued today's learner with the visuospatial skills needed for learning chemistry via spatial intelligence but that chemistry educators are not taking advantage of this readiness.

Presenting chemistry concepts to learners via multiple intelligences is desirable since a wider spectrum of learners could be reached thereby. However, the possibility still exists for the desired learning not to take place since both constructive and destructive interference can result from multiple representations of a concept. Kirby (100) explains that verbal and spatial intellectual processes can complement each other for more effective learning or they may promote competing understandings which impede the desired learning. Schnotz (101) found this to be true even among university students. Based on their experiences with using spatial-visual learning aids with undergraduate chemistry students, Sanger (47) recommends that their use be done carefully to avoid new problems of misconceptions, and based on their experience, Lang and Towns (45) caution that college students may incorrectly understand the concept of degeneracy by the way they interpret graphical representations of wave functions.

Gardner’s theory offers promise of increased success for all learners and accommodating multiple Intelligences is an approach that could make chemistry more accessible to today’s students. Reports of applications of this theory to the learning of college chemistry are very few (92, 94, 96). Well-documented and carefully analyzed research is needed to determine its applicability. It is worth investigating whether the theory of multiple intelligences can be successfully applied in the learning of college chemistry. This research is intended to test the hypothesis that presenting chemistry concepts in formats that are compatible with a learner’s multiple intelligence strengths will result in more effective learning than would occur if the formats did not reflect the learner’s multiple intelligence strengths.

CHAPTER III

Experimental

PRELIMINARY INVESTIGATION

Objective

During the 2000-2001 school year a pilot study (Appendix A) was undertaken in order to determine which intelligences predominated in chemists and whether it was possible to differentiate between linguistic, spatial and logical-mathematical formats in the way chemistry was understood by chemists (102).

Sample

Twenty-one graduate students enrolled in the Department of Chemistry and Biochemistry were investigated for their preferences of having chemistry concepts presented in linguistic, spatial or logical-mathematical format. They were distributed among the sub-disciplines of chemistry as follows: 6 in analytical chemistry, 3 in biochemistry, 4 in chemical education, 1 in inorganic chemistry, 4 in organic chemistry, 3 in physical chemistry.

Instruments

There were two instruments used in this study, an on-line chemistry format preference instrument (Appendix B) and a multiple intelligence instrument (Appendix C). The chemistry format preference instrument consisted of eight statements, each of which expressed a chemical concept and was accompanied by an explanation/elaboration or example expressed in linguistic, spatial and logical-mathematical formats. Subjects were asked to use a 3-point rating system to indicate their preference for the format in which the explanation/elaboration or example was expressed by giving a rating of 3 (most preferred) to 1 (least preferred). The multiple intelligence instrument was the Multiple Intelligence Assessment Scales (MIDAS), developed over a six-year period by C. Branton Shearer (103) and its construct, concurrent and predictive validity were established through a series of studies involving adults in various occupational groups and college students. Its reliability was established in terms of its internal consistency, temporal stability, multi-informant agreement, and cultural bias. It measures the eight intelligences identified by Gardner.

Procedure

Each graduate student participant was asked to follow the protocol for each of the eight concepts on the format preference instrument and indicate her or his preference (3, 2 or 1) of format for the explanation/elaboration or example associated with each concept. They were subsequently individually interviewed (Appendix D) and asked to explain their choices. Finally, each participant took the MIDAS test, recording answers to the questions on a scantron according to instructions provided (Appendix E). These were sent for analysis to the author, Shearer (103), who produced for each subject a multiple intelligence profile.

Observations and Implications

Although there was a small sample size for the overall study, which precluded definitive conclusions that can be generalized, some important trends can be identified from the results.

T-test analysis of the scores from the MIDAS (Table 3.1) revealed that the graduate chemistry students had high logical-mathematical and intra-personal intelligence strengths. The next strongest intelligences were spatial, linguistic and naturalistic, all of identical moderate strength at 2-tailed significance level of $\alpha = 0.05$. This finding supports Gardner's hypothesis that the intelligences needed for success in the physical sciences are linguistic, spatial and logical-mathematical. That graduate chemistry students are also high in intra-personal intelligence is an important finding, since among the components that Shearer identifies for intra-personal intelligence is personal knowledge (Table 3.2) which is related to metacognition, the ability to ask one's self appropriate questions when learning a concept or solving a problem. Thus, besides supporting Gardner's proposition that linguistic, spatial and logical-mathematical intelligences are needed for successful learning in the physical sciences, the current study identified intra-personal intelligence as also being an important component of the intelligence profile of successful learners in chemistry. This is consistent with research reports that identify reflective thinking and metacognition (104) as characteristics that promote science learning.

Table 3.1: Means of MIDAS Profiles of Chemistry Graduate Student Subjects

MIDAS	Mean Score ± standard deviation (strength)
Logical-mathematical	64 ± 11 (high)
Intra-personal	60 ± 11 (high)
Spatial	57 ± 16 (moderate)
Linguistic	56 ± 15 (moderate)
Naturalistic	56 ± 16 (moderate)
Inter-personal	53 ± 16 (moderate)
Musical	50 ± 23 (moderate)
Kinesthetic	49 ± 16 (moderate)

Shearer's scale: very high ≥ 80; high 60-79; moderate 41-59; low 20-40; very low <20.

Table 3.2: Shearer's Subscales* of Logical-mathematical and Intra-personal Intelligences

Logical-mathematical	Intra-personal
School math	Personal knowledge
Logical games	Calculations
Everyday math	Spatial problem-solving
Every-day problem-solving	Effectiveness

*These subscales identify specific areas of skills Shearer associates with the respective intelligences

Pearson correlations were seen between logical-mathematical and spatial intelligences, between logical-mathematical and intra-personal intelligences, between logical-mathematical and kinesthetic intelligences, between linguistic and intra-personal intelligences and between spatial and kinesthetic intelligences (Table 3.3). This means that chemists who are strong in logical-mathematical intelligence are also likely to be strong in spatial intelligence, in intra-personal intelligence, and in kinesthetic intelligence; chemists who are strong in linguistic intelligence are also likely to be strong in intra-personal intelligence; and chemists who are strong in spatial intelligence are also likely to be strong in kinesthetic intelligence. The importance of intra-personal intelligence to chemistry is again underscored by its significant correlations with logical-mathematical and linguistic intelligences. The significant correlations of kinesthetic intelligence with logical-mathematical and spatial intelligences suggest that it could be helpful to chemistry students. Both Brown Wright (52) and Sweet (99) were able to help students grasp chemistry concepts by making use of their kinesthetic intelligence. One of Sweet's high school students expressed his knowledge of how nuclear reactors work by building a model; one of Brown-Wright's first-year college chemistry students expressed delight when using her arms to represent O-H bonds in a water molecule enabled her to understand the relationship between bond angle and polarity.

Table 3.3: Correlations Between Graduate Chemistry Student Multiple Intelligence Scores and Format Preferences

Intelligence	Intelligence			Format Preference	
	Linguistic	Spatial	Log-math	Linguistic	Log-math
Logical-mathematical	n.s.	.56**		n.s.	n.s.
Inter-personal	.52*	n.s.	n.s.		
Intra-personal	.55**	n.s.	.61	-.56**	n.s.
Kinesthetic	n.s.	.63*	.48*		
Musical	n.s.	n.s.	n.s.	-.45*	.56**

N = 21
n.s. = not significant at the $p < .05$ level
*$p < .05$
**$p < .01$

The maximum possible score that each subject could have assigned each of the formats on the chemistry format preference instrument was 24 and the minimum was 8. The mean (± standard deviation) of the scores assigned by all the subjects were linguistic 18 (± 3), spatial 15 (± 3) and logical-mathematical 16 (± 3). T-tests showed that the chemistry graduate students had a preference for linguistic format over logical- mathematical and spatial formats (Table 3.4). There was no significant difference between their preferences for logical-mathematical and spatial formats at the significance level of $\alpha = 0.05$. The similar variance seen for all three formats indicate that overall the representations all had the same level of acceptance among the graduate students.

The explanations offered by the graduate students for their choices of preference among the three formats used in the explanations/elaborations or examples of the chemistry concepts ranged from reflecting their status as students ("That's how I learned it") to a willingness to intellectually process the information presented ("I can see it right away in this format."). Some sample responses are listed in Table 3.5.

Table 3.4: Preferences of Graduate Students for Delivery Format of Chemical Concepts

Format	Mean ± s
Linguistic	18 ± 3
Spatial	15 ± 3
Logical-mathematical	16 ± 3

N = 21
Maximum 24, minimum 8.

Table 3.5: Sample Explanations for Format Preferences

I never saw it before
That's how I learnt it
It doesn't mean anything to me
It doesn't make sense to me
It took too long to go through and figure out
The lines/arrows make it confusing
The lines/arrows make it very clear
I can see it right away in this format
It's difficult to choose between these two
That's how I teach it
That's how I think about it

EXPERIMENTAL DESIGN

Population and Sample

The experimental samples for this thesis were subgroups of students selected originated from the population of students enrolled in Principles of Chemistry, CH301 at the University of Texas (Appendix F). Each fall semester approximately 500 students are registered in most sections of the course. A few sections cater to students for whom it is felt specialized treatment is required (majors, first-generation college students, graduates of small high schools) and have enrollments of less than 100 students. At the beginning of the semester students from all sections of CH 301 were invited to take part in the study. The intent of the study and the procedure to be followed were explained verbally and in writing, and those who agreed to take part signed a consent sheet. The subjects were randomly assigned to three experimental groups of approximately equal numbers of students. Each group would receive the intervention tutorial in a different format whenever the treatment was administered.

Instruments

Two types of instruments were used in this study: a chemistry instrument and a multiple intelligence instrument. The chemistry instrument consisted of pre- and post-quizzes associated with a series of tutorials written to cover three chemistry concepts: (1) Mole Concept (2) Chemical Bonding and (3) Gas Laws. Each tutorial was translated into linguistic, spatial and logical-mathematical formats, representative of the three intelligences identified by Gardner as most needed for the physical sciences. The tutorials were audiovisual, delivered via compact discs (Appendices G to O), and were in all respects identical for each topic, except for what the subject saw on the screen: the linguistic format showed words, the spatial format showed shapes and the logical-mathematical format showed symbolic representations. The multiple intelligence instrument was the MIDAS described in the preliminary study (Appendix C).

Time and Location

The experiment was conducted during the Fall 2002 semester, the Spring 2003 semester and the Summer 2003 sessions. The chemistry treatment took place in a student computer laboratory in the Department of Chemistry and Biochemistry. Subjects had the option to do the MIDAS in this location or in a location of their choice.

Instructional Treatment

The instructional treatment was delivered electronically on CD-ROM at intervals during the duration of the CH 301 course, always just before the topic was presented in lecture. The instructional treatment was the second step in the three-phase protocol consisting of a sequence of 1) pre-quiz, 2) tutorial and 3) post-quiz; and was administered shortly before the topic was introduced in the CH301 lecture. For each topic the scores attained on the pre-quiz were used as measures of students' understanding of the concepts before treatment and the scores attained on the post-quiz were used as measures of their understanding of the concepts after receiving instruction via the tutorials. At the first sitting the concept used was "Mole Concept", with each group receiving it in either linguistic, spatial or logical-mathematical format. The protocol was repeated for the topic "Chemical Bonding" about midway through the course, just before it was presented in lecture, each group receiving it in a format that was different than they earlier received. Finally, near the end of the course, just before "Gas Laws" was presented in lecture, the subjects had the pre-test, tutorial, post-test protocol for this third topic, the tutorial for each group being in the format not yet experienced. On each occasion the pre-quiz (Appendices P, R, T), the post-quiz (Appendices Q, S, U), and the tutorial topic were identical for all the groups. At the end of the experiment all subjects had experienced all the formats, though for a different concept. A tabular representation of the experimental design appears in Table 3.6.

Measurement of Multiple Intelligences

For the final part of the experiment all subjects took the MIDAS (Appendix C), filling out their responses on scantrons according to instructions provided (Appendix V). This was administered after the instructional treatment in order to prevent the MIDAS from becoming a sample contaminant by prejudicing the subjects toward thinking they ought to learn from a particular format. The scantrons were sent to Shearer (103) who returned a report of each subject's multiple intelligences profile. A score of 80 or above he designated as very high in that intelligence, a score in the range of 60-79 he designated as high, 41-59 was designated moderate, 20-40 was designated low; and less than 20 was designated very low.

Evaluation by Subjects

After each post-test the subjects were asked to give a subjective assessment of their experience by means of an evaluation instrument that consisted of eleven questions on a five-point Likert scale (Appendices W, X, Y).

Table 3.6: Summary of Treatment Schedule for Subject Groups

TOPIC	MULTIPLE INTELLIGENCE FORMAT OF TUTORIAL		
	GROUP 1	GROUP 2	GROUP 3
Mole Concept	LINGUISTIC	SPATIAL	LOGICAL-MATHEMATICAL
Chemical Bonding	SPATIAL	LOGICAL-MATHEMATICAL	LINGUISTIC
Gas Laws	LOGICAL-MATHEMATICAL	LINGUISTIC	SPATIAL

Chapter IV

RESULTS

NUMBER OF PARTICIPANTS

Fall Subjects

As indicated in Table 4.1, 143 subjects started the experiment in the Fall, completing the first session, 72 continued to the second session and 61 completed all three sessions and the MIDAS. Of these, three were disqualified on the basis of having received one format twice and not receiving one format.

Spring Subjects

In the Spring, two hundred and twelve (212) subjects completed the first session, 182 continued to the second session and 163 completed all three sessions. Of these, one did not return the MIDAS and one was disqualified on the basis of having received one format twice and not receiving one format.

Summer Subjects

In the Summer, one hundred and forty-one (141) subjects started the experiment. Of these 17 were registered for the first-session course and 124 were in the whole-session course. One hundred and twenty-five (125) of the original subjects continued to the second session and 117 completed all three sessions. Of these, two were disqualified on the basis of having received one format twice and not receiving one format.

Table 4.1: Number of Subjects Involved in Experiment

	Session 1 (Mole Concept)	Session 2 (Chemical Bonding)	Session 3 (Gas Laws)	Three formats (linguistic, spatial, logical-mathematical)	Three formats and MIDAS
Fall 2002	143	72	61	58	58
Spring 2003	212	182	163	162	161
Summer 2003	141	125	117	115	115
Total	496	379	341	335	334

SAMPLE SIZE

A total of 334 subjects completed the experiment, having followed the protocols for all three topics in three different formats and also done the Multiple Intelligence Development Assessment Scales. The 334 subjects were distributed as follows: Group one, 115; Group two, 112; and Group three, 107.

The difference between pre-quiz and post-quiz was used as a measure of the amount of learning that took place as a result of the tutorial. For each subject, the ∆ quiz (post-quiz – pre-quiz) scores were normalized as percentage change and compared for ranking; in some cases subjects achieved a post-quiz score of 100% for Concept 1 (Mole Concept). It was observed that in 15 of these cases the pre- and post-quiz scores were identical or very close and produced a ∆ quiz value which was smaller than ∆ quiz for one or both of the other concepts (Table 4.2). In these cases, it was impossible to determine that learning from the format used in Concept 1 was indeed less that learning from the other formats and since no meaningful comparison could be made these data were eliminated. The remaining 319 subjects comprised the sample and their data were statistically analyzed in order to answer the research questions (Table 4.3). Included in the sample are nine (9) subjects (four in Fall 2002, four in Spring 2003 and one in Summer 2003) who received all three formats and all three topics but for whom the formats for Chemical Bonding and Gas Laws were reversed.

Table 4.2: Data for Analysis[1]

	Group 1 (linguistic → spatial → logical-mathematical)	Group 2 (spatial → logical-mathematical → linguistic)	Group 3 (logical-mathematical → linguistic → spatial)	All Groups
Number of subjects completing experiment	115	112	107	334
Number of subjects with small Δ $quiz_{mole\ concept}$	6	2	7	15
Sample size	109	110	100	319

[1]The number of subjects in each category is indicated

Table 4.3: Data Used in Analysis

Group	**1**	**2**	**3**	**Total**
sample size*	109	110	100	319
order of 2nd and 3rd formats reversed	4	4	1	9

*Used in analysis

CHAPTER V

Analysis

CHARACTERIZATION OF SUBJECTS

Distribution of Intelligences

Frequency distributions (Table 5.1) of the MIDAS intelligence scores of the 319 subjects indicate normal distribution of linguistic (Figure 5.1), spatial (Figure 5.2) and logical-mathematical (Figure 5.3) intelligences. This is evidenced by skewness and kurtosis values within a range of ±1.0, and which are also less than half the respective standard errors in the case of skewness.

Distribution of Intelligence Strengths

When the intelligence scores of all the students for each intelligence are grouped according to Shearer's five categories of intelligence strengths (very low, low, moderate, high, very high) a normal distribution is also seen (Table 5.2, Figures 5.4 to 5.6).

Comparison of Intelligence Means

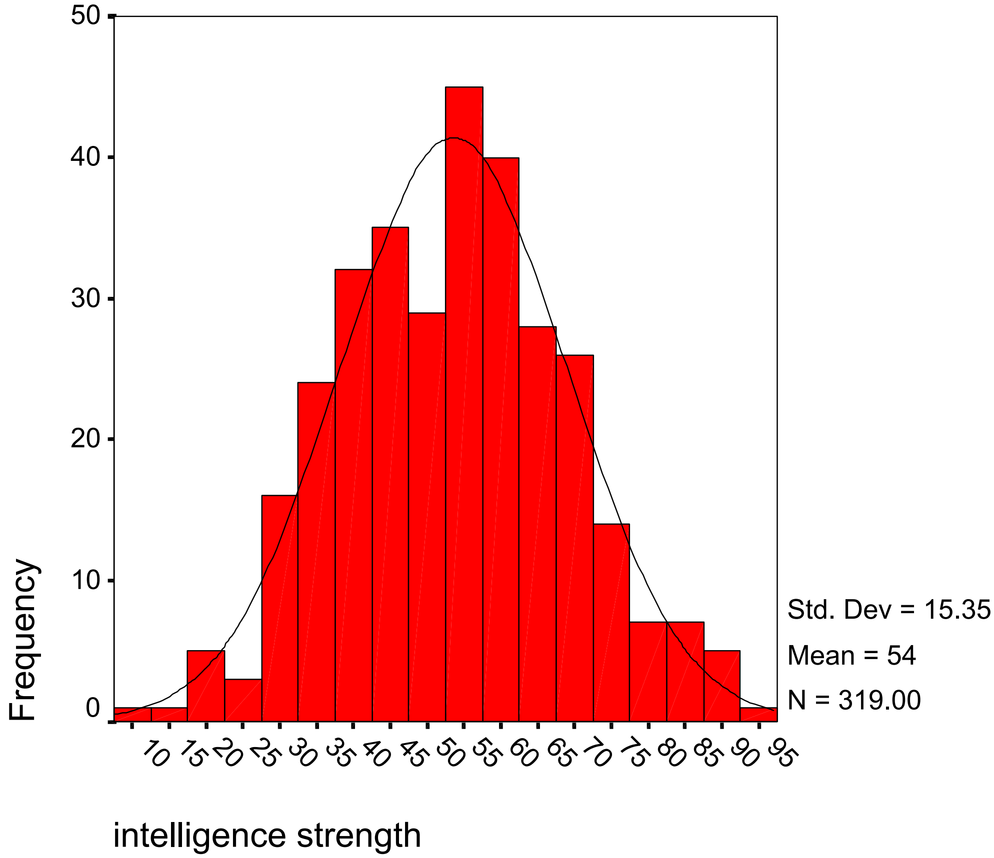
(i) Strength Values

The mean values of all the subjects' intelligence strengths as determined by the MIDAS fell in the moderate range and were 53.59, 52.20 and 56.29, respectively, for linguistic, spatial and logical-mathematical intelligences (Table 5.3). Pair-wise comparisons of the means showed that whereas at the 95 % confidence limit the mean value of their linguistic intelligence strength is not

Table 5.1: Frequency Distribution of Intelligences

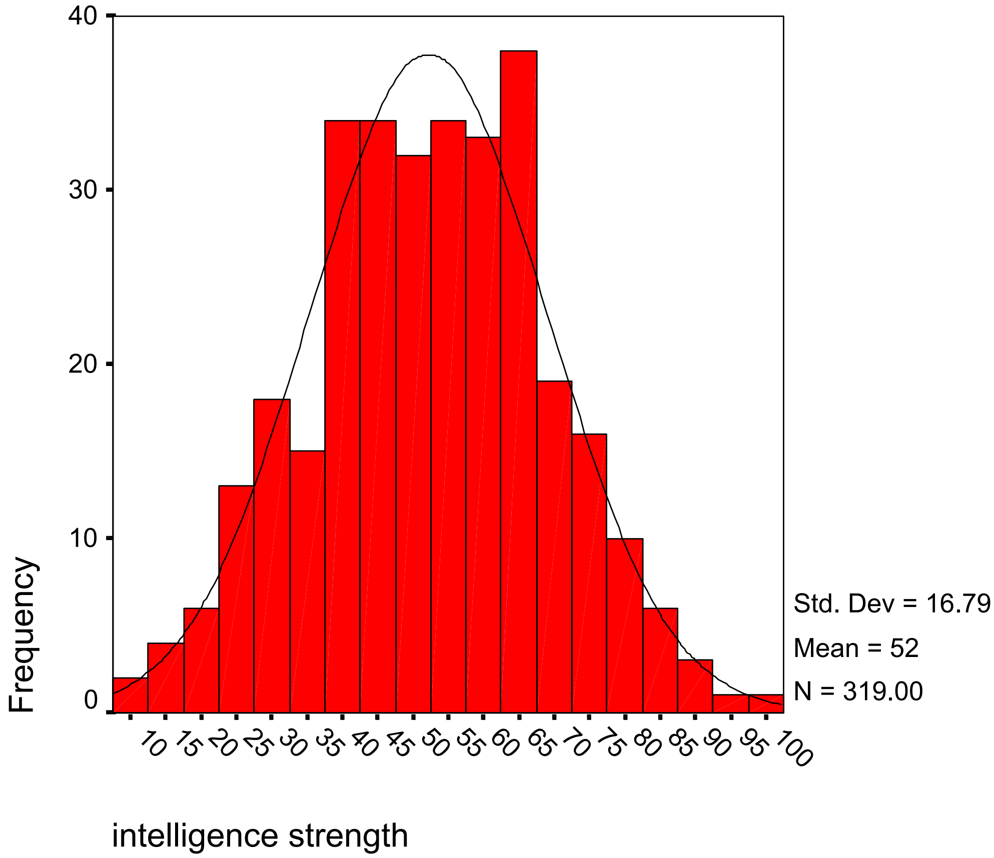
Intelligence	Mean	Median	Mode	Std. Dev.	Skewness [b]	Kurtosis [c]
Linguistic	53.6	54.0	54	15.4	.05	-.23
Spatial	52.2	53.0	38	16.8	-.02	-.29
Logical-mathematical	56.3	56.0	52[a]	15.1	-.04	-.26

Shearer's scale: very high ≥ 80; high 60-79; moderate 41-59; low 20-40; very low <20
N = 319
[a]Multiple modes exist. The smallest value is shown.
[b]Error = .14
[c]Error = .27



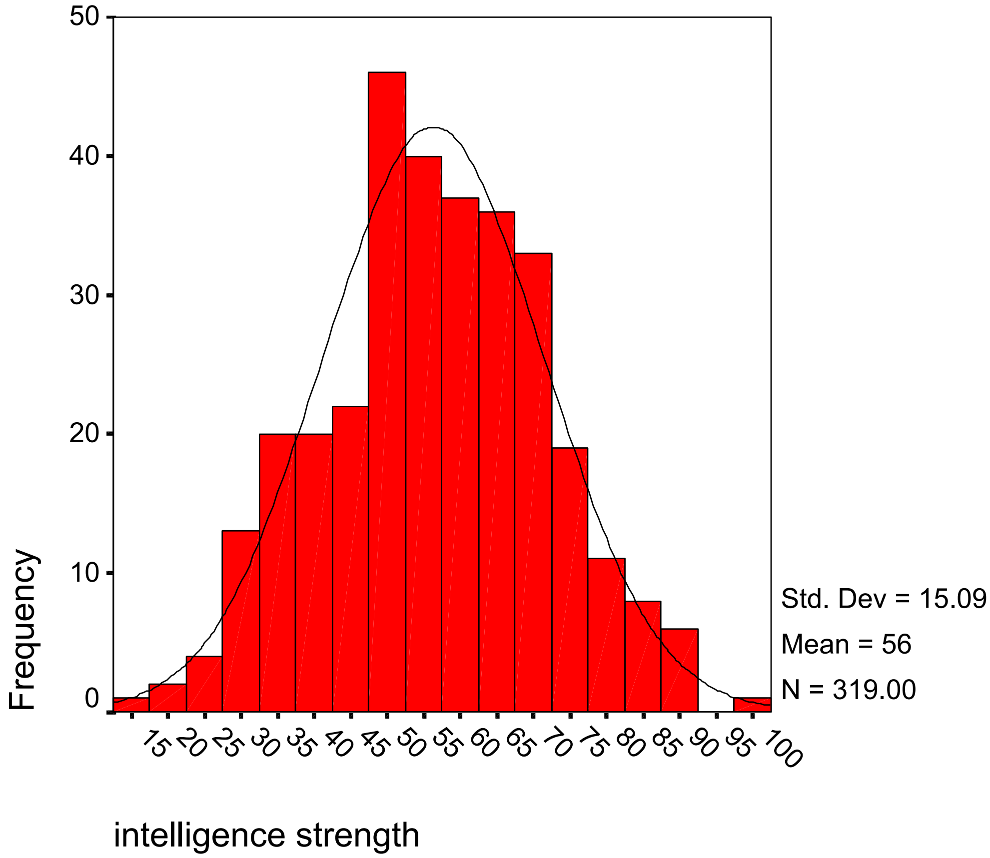
Shearer's scale: very high ≥ 80; high 60-79; moderate 41-59; low 20-40; very low <20.

Figure 5.1: Frequency Distribution of Linguistic Intelligence with Normal Curve Superimposed



Shearer's scale: very high ≥ 80; high 60-79; moderate 41-59; low 20-40; very low <20.

Figure 5.2: Frequency Distribution of Spatial Intelligence with Normal Curve Superimposed



Shearer's scale: very high ≥ 80; high 60-79; moderate 41-59; low 20-40; very low <20.

Figure 5.3: Frequency Distribution of Logical-Mathematical Intelligence with Normal Curve Superimposed

Table 5.2: Frequency Distribution of Intelligence Levels

Intelligence	Mean	Median	Mode	Std. Dev.	Skewness [a]	Kurtosis [b]
Linguistic	3.2	3.0	3	.9	-.00	-.21
Spatial	3.1	3.0	3	.9	-.10	-.32
Logical-mathematical	3.3	3.0	3	.8	.00	-.48

Level (intelligence category): very high 5; high 4; moderate 3; low 2; very low 1.
N = 319
[a]Error = .14
[b]Error = .27

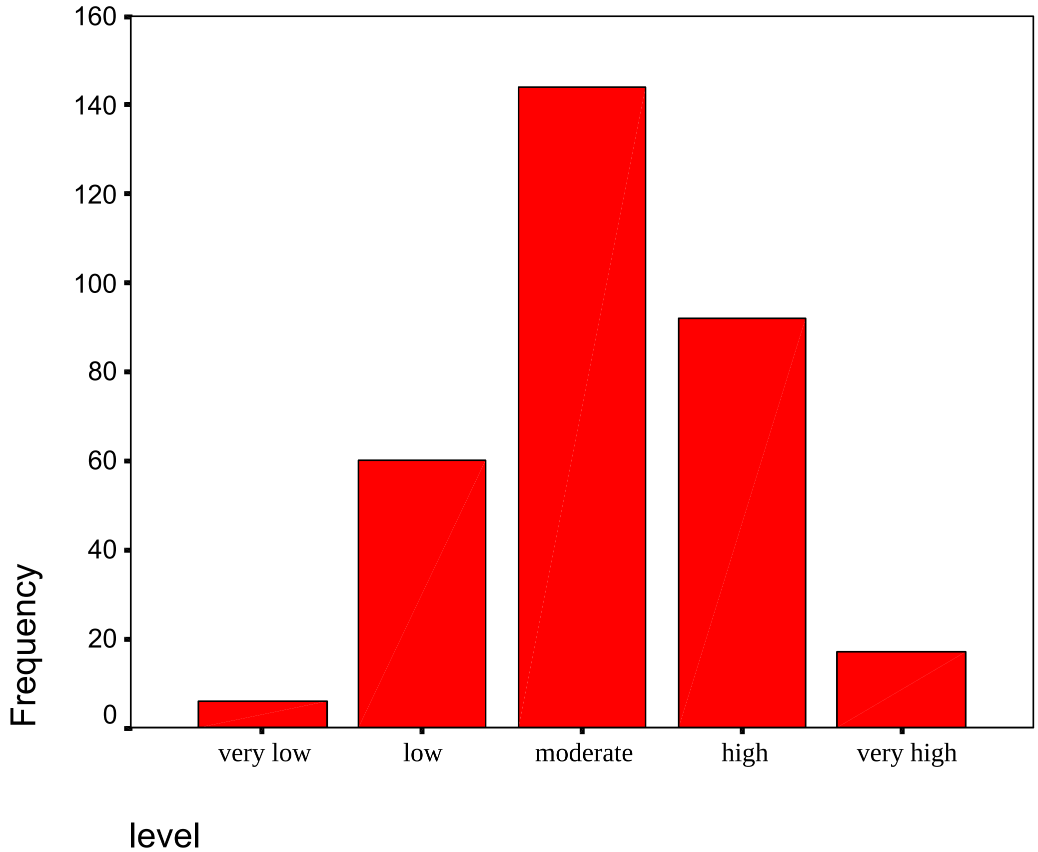


Figure 5.4: Frequency Distribution of Levels of Linguistic Intelligence Strengths

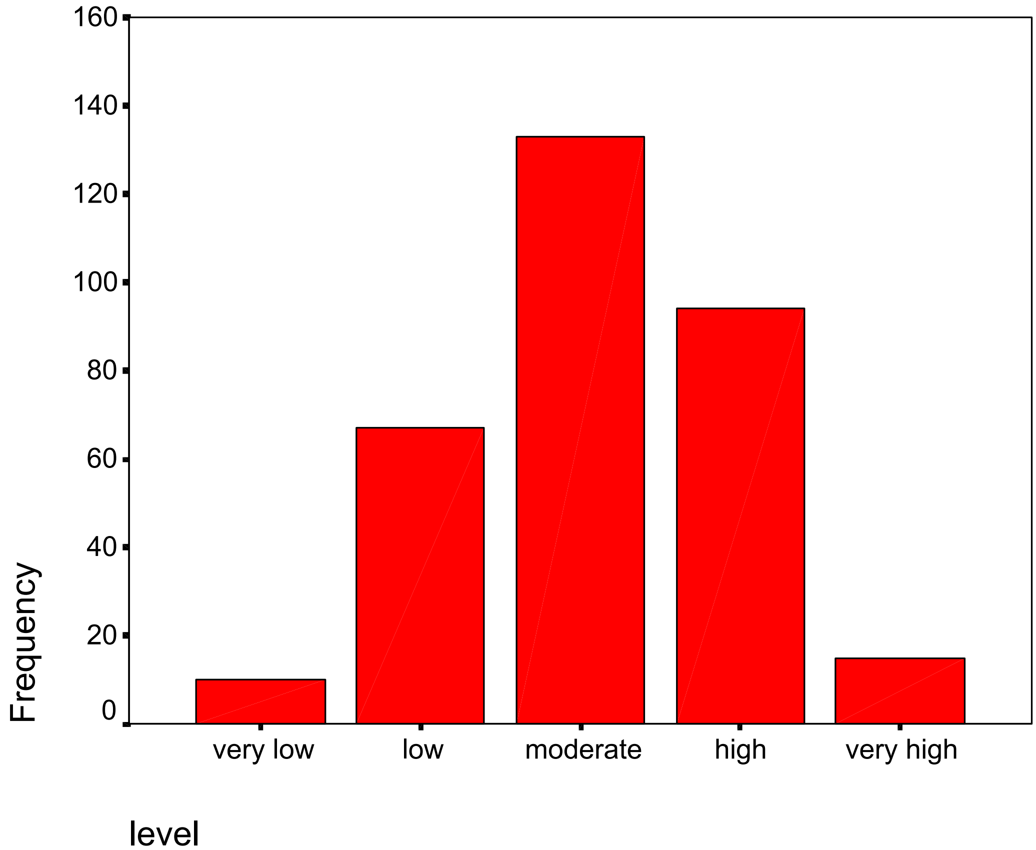


Figure 5.5: Frequency Distribution of Levels of Spatial Intelligence Strengths

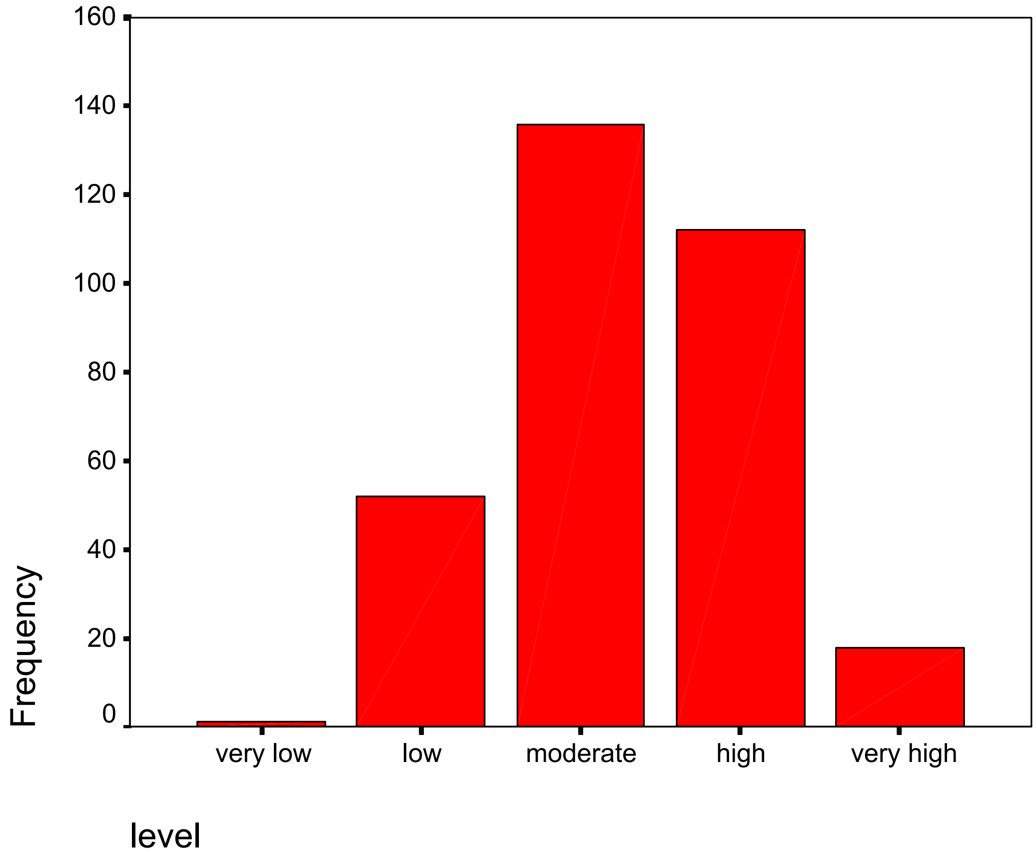


Figure 5.6: Frequency Distribution of Levels of Logical-Mathematical Intelligence Strengths

Table 5.3: Comparison of Intelligence Strength Means

Intelligence Pair	Mean	Std. Dev.	Mean Diff.	Std. Error of Mean Diff.	t-value[1]	95% Confidence Interval	
Linguistic Spatial	53.6 52.2	15.4 16.8	1.4	1.1	1.3[n.s.]	-.7	3.5
Logical-mathematical Linguistic	56.3 53.6	15.1 15.4	2.7	.9	2.9*	.9.	4.6
Logical-mathematical Spatial	56.3 52.2	15.1 16.8	4.1	.7	5.8*	2.7	5.5

[1]df = 318

n.s. = not significant at the $p < .05$ level

*$p < .05$

significantly higher than the mean value of their spatial intelligence strength, the mean values of both linguistic and spatial intelligence strengths are significantly smaller than the mean value of their logical-mathematical intelligence strength ($p < .05$).

(ii) Correlations

Table 5.4 shows that, as with the graduate students, for the undergraduate population there is correlation between linguistic and logical-mathematical intelligence strengths (r = .40) and between spatial and logical-mathematical intelligence strength (r = .70). In addition, linguistic and spatial intelligence strengths are also correlated (r = .29) in the undergraduate subjects, possibly reflecting the greater involvement of the younger generation in pastimes such as video games that utilize spatial skills. The size of the r values indicate that undergraduate students in first-year college chemistry are very likely to have similar spatial and logical-mathematical intelligence strengths but not as likely to have similar linguistic and spatial intelligence strengths or similar linguistic and logical-mathematical intelligence strengths. All these correlations are significant ($p < .01$).

Intelligence Clusters

(i) Definition

In order to see more clearly how the intelligence strengths compared, Shearer's five levels of intelligence strength were designated numerical codes as follows: very high 5, high 4, moderate 3, low 4, very low 1. For each subject

Table 5.4: Correlations between Intelligence Strengths

Intelligence	Linguistic	Spatial	Logical-mathematical
Linguistic			
Spatial	.29*		
Logical-mathematical	.40*	.70*	

N = 319
*p < .01

a three-digit intelligence cluster were created. These clusters consisted of three digits representing, in this order, the codes for their linguistic, spatial and logical-mathematical intelligence strengths.

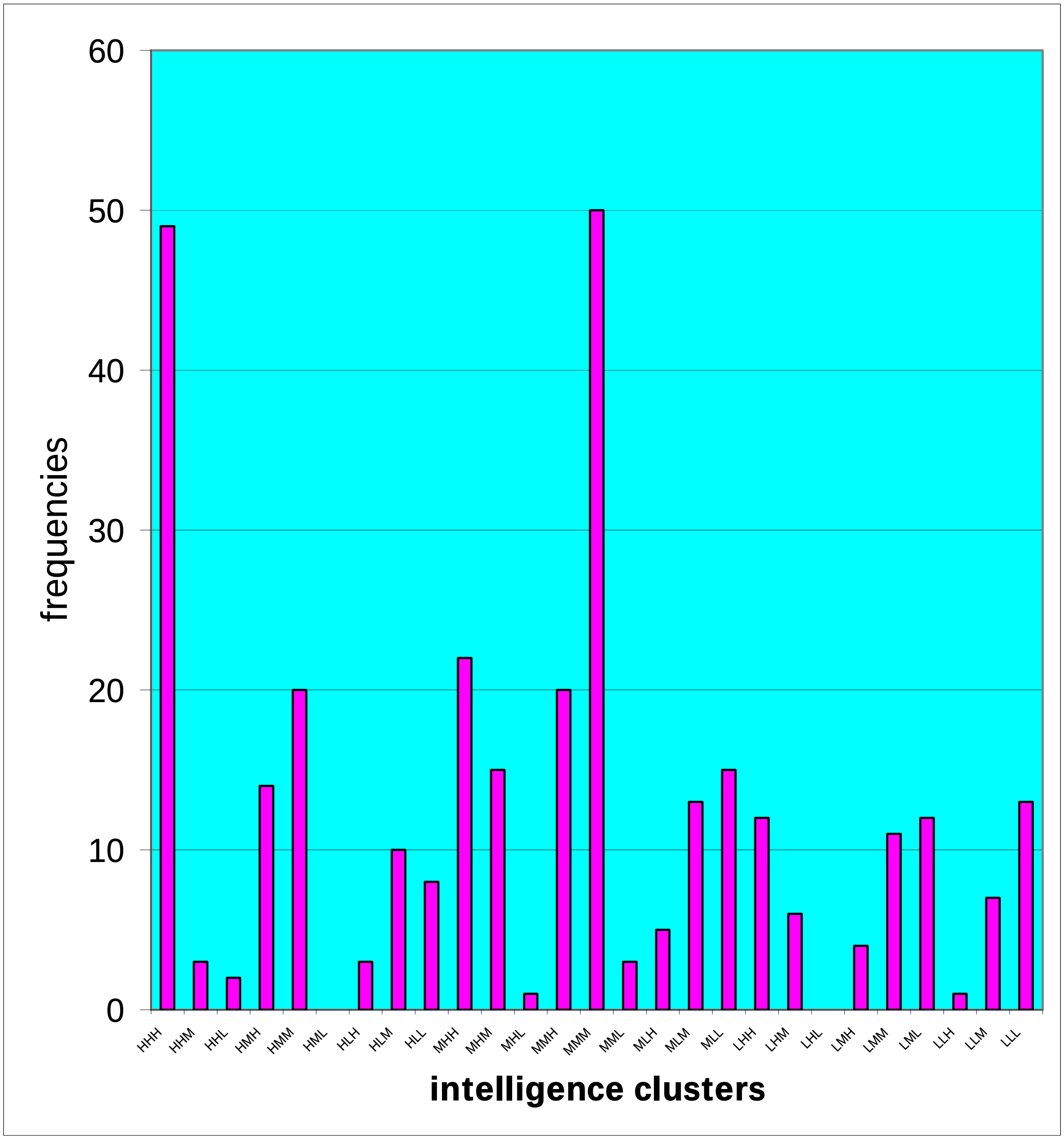
(ii) Population

The most highly populated intelligence clusters were those in which the subjects showed identical or similar levels for all three intelligences (Table 5.5). Figure 5.7 shows that when very high and high were combined as high (H) and low and very low were combined as low (L), 49 subjects (more than 15 %) were high (H) in all three intelligences, 50 subjects (16 %) were moderate (M) in all three intelligences and 13 subjects (4 %) were low in all three intelligences, for a total of more than 35 % of the subjects with identical strengths in all three intelligences. Almost half (49%) of the subjects were at similar strength in the three intelligences, with two intelligences at high level and one at moderate level (39 subjects), or two intelligences at moderate level and one at high level (55 subjects), or two intelligences at moderate level and one at low level (27 subjects), or two intelligences at low level and one at moderate level (35 subjects). Only 26 subjects had combinations of high and low intelligences only and 25 subjects had each of the intelligences at a different level (8 % each).

Table 5.5: Frequencies of Intelligence Clusters

x-label	code	MDS-LIN	MDS-SPA	MDS-LGM	frequency	percent
1	555	very high	very high	very high	2	0.6
2	554	very high	very high	high	1	0.3
3	544	very high	high	high	6	1.9
4	543	very high	high	moderate	1	0.3
5	535	very high	moderate	very high	1	0.3
6	534	very high	moderate	high	1	0.3
7	533	very high	moderate	moderate	2	0.6
8	524	very high	low	high	1	0.3
9	523	very high	low	moderate	2	0.6
10	455	high	very high	very high	5	1.6
11	454	high	very high	high	2	0.6
12	445	high	high	very high	7	2.2
13	444	high	high	high	26	8.2
14	443	high	high	moderate	2	0.6
15	442	high	high	low	2	0.6
16	434	high	moderate	high	12	3.8
17	433	high	moderate	moderate	18	5.6
18	424	high	low	high	2	0.6
19	423	high	low	moderate	7	2.2
20	422	high	low	low	7	2.2
21	413	high	very low	moderate	1	0.3
22	411	high	very low	very low	1	0.3
23	355	moderate	very high	very high	1	0.3
24	354	moderate	very high	high	3	0.9
25	353	moderate	very high	moderate	1	0.3
26	345	moderate	high	very high	2	0.6
27	344	moderate	high	high	16	4.5
28	343	moderate	high	moderate	14	4.4
29	342	moderate	high	low	1	0.3
30	334	moderate	moderate	high	20	6.3
31	333	moderate	moderate	moderate	50	16.0
32	332	moderate	moderate	low	3	0.9
33	324	moderate	low	high	5	1.6
34	323	moderate	low	moderate	12	3.8
35	322	moderate	low	low	11	3.4
36	313	moderate	very low	moderate	1	0.3
37	312	moderate	very low	low	4	1.3
38	244	low	high	high	12	3.8
39	243	low	high	moderate	5	1.6
40	234	low	moderate	high	3	0.9
41	233	low	moderate	moderate	11	3.4

42	232	low	moderate	low	11	3.4
43	224	low	low	High	1	0.3
44	223	low	low	moderate	6	1.9
45	222	low	low	low	9	2.8
46	213	low	very low	moderate	1	0.3
47	212	low	very low	low	1	0.3
48	143	very low	high	moderate	1	0.3
49	132	very low	moderate	low	1	0.3
50	123	very low	low	moderate	1	0.3
51	122	very low	low	low	2	0.6
52	112	very low	very low	low	1	0.3



H: high; M: moderate; L: low
Order: linguistic, spatial, logical-mathematical

Figure 5.7: Frequency Plot of Multiple Intelligence Profiles

EXTENT OF LEARNING

Distribution

The score difference (post-quiz score – pre-quiz score) was used to indicate the amount of learning which took place. The distribution of learning from all three tutorial formats (Table 5.6, Figures 5.8, 5.9, 5.10) show normal distribution (values of ± 1 are considered excellent and values of ± 2 are acceptable for skewness and kurtosis.)

Effects

Mauchly's test (Table 5.7) indicates that variances (format) and covariance (format x time) are similar across time (pre- and post-quizzes) at the significance level of $\alpha = .05$ and so sphericity can be assumed.

(i) Formats

The mean amounts of learning that occurred via the various tutorial formats were linguistic 16.54, spatial 15.38, and logical-mathematical 15.00. There is no main effect of format and so learning from these formats do not produce statistically different results at the significance level of $\alpha = .05$ for the 319 subjects (Table 5.8). Format is not a determinant for pre-quiz or for the difference between pre-quiz and post-quiz. The correlation between learning from the different formats is small and non-significant (Table 5.9), indicating that learning from the different formats was independent of each other. The eta squared value for format in Table 5.10 indicates that format can account for only 0.2 % of the variance in post-quiz scores.

Table 5.6: Frequency Distribution of Extent of Learning

Intelligence	Mean	Median	Mode	Std. Dev.	Skewness [a]	Kurtosis [b]
Linguistic	16.54	16.67	0	20.96	.49	1.16
Spatial	15.38	11.76	0	21.19	.29	.28
Logical-mathematical	15.00	16.67	0	20.10	.24	-.01

N = 319
[a]Error = .14
[b]Error = .27

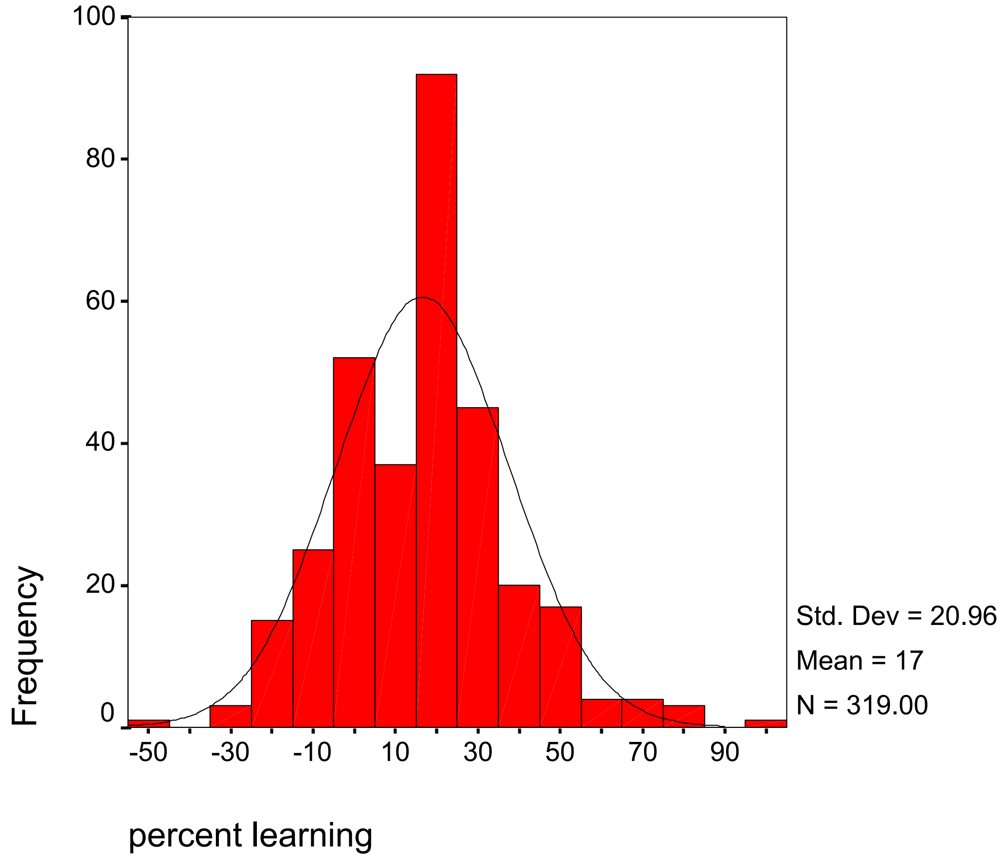


Figure 5.8: Frequency Distribution of Extent of Learning from Linguistic Format

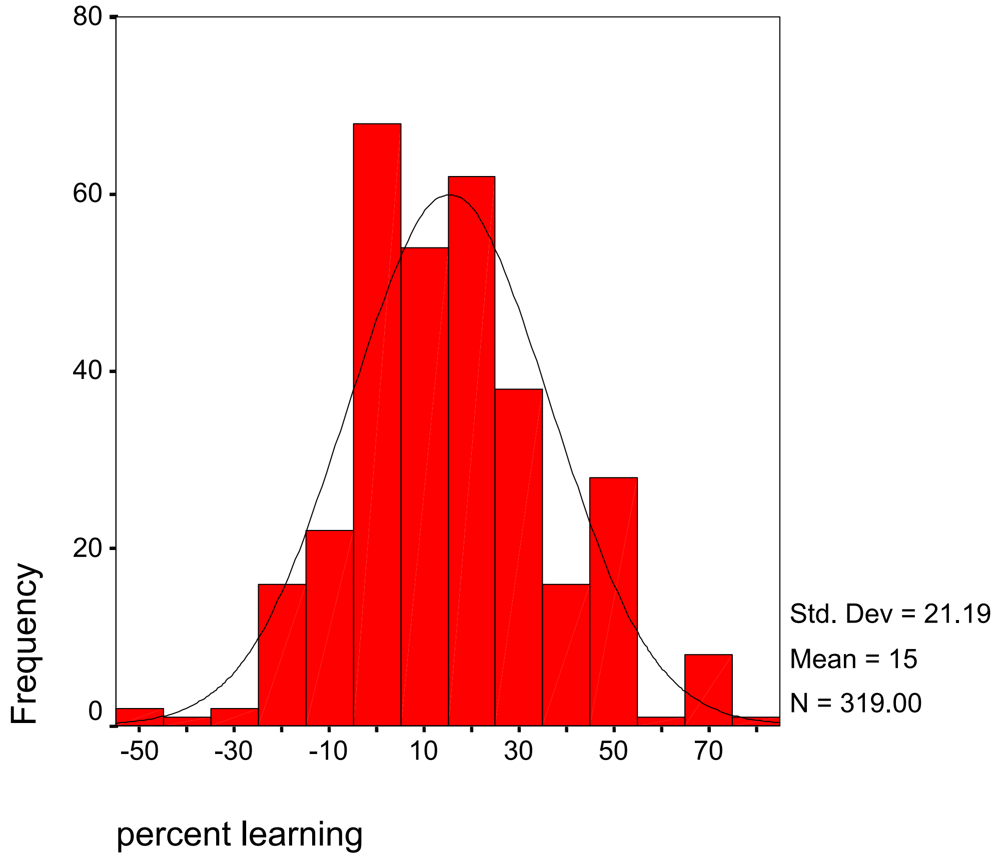


Figure 5.9: Frequency Distribution of Extent of Learning from Spatial Format

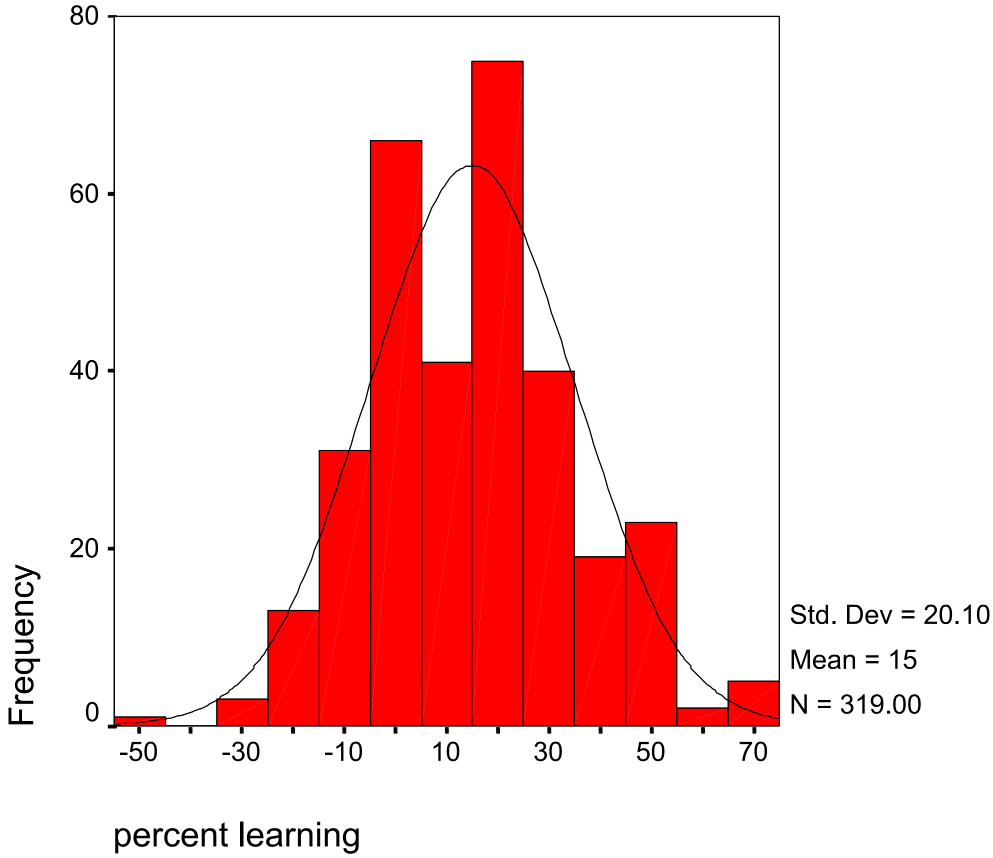


Figure 5.10: Frequency Distribution of Extent of Learning from Logical-Mathematical Format

Table 5.7: Mauchly's Test of Sphericity for Format

Within-Subject Effect	Mauchly's W	Approx. Chi-Square	df	Sig
FORMAT	1.00	.51	2	.78
TIME	1.00	.00	0	
FORMAT * TIME	1.00	.42	2	.81

[a]Design: Intercept
Within Subjects Design: FORMAT+TIME+ FORMAT * TIME

Table 5.8: Comparison of Amounts of Learning by Format

Format Pair	Mean	Std. Dev.	Mean Diff.	Std. Error of Mean Diff.	t-value[1]	95% Confidence Interval	
Linguistic Spatial	16.5 15.4	21.0 21.2	1.2	1.6	.72 n.s.	-2.0	4.4
Linguistic Logical-mathematical	16.5 15.0	21.0 20.1	1.5	1.6	.96 n.s.	-1.6	4.7
Spatial Logical-mathematical	15.4 15.0	21.2 20.1	.4	.6	.23 n.s.	-2.8	.5

[1]df = 318

n.s. = not significant at the $p < .05$ level

Table 5.9: Correlations between Learning via Different Formats

Intelligence	Linguistic	Spatial	Logical-mathematical
Linguistic			
Spatial	.05		
Logical-mathematical	.04	.04	

N = 319
None of these correlations was significant

Table 5.10: Test of Within-Subjects Effects for Tutorial Formats

Within-Subjects Effect	df	F	Eta Squared
FORMAT			
Sphericity assumed	2	.54	.002
TIME			
Sphericity assumed	1	498.26	.611
FORMAT x TIME			
Sphericity assumed	2	.65	.002

(ii) Pre-quiz and Post-quiz scores

Figure 5.11 shows main effect for pre-quiz and post-quiz scores. Pre-quiz scores were almost identical whether subjects subsequently got the tutorial in linguistic, spatial or logical-mathematical format (31.66, 31.39, 31.57, respectively) but post-quiz scores that did not differ significantly from different formats. Overall, the groups started out with similar knowledge in each of the three concepts used in the experiment and in every case learning took place to the same extent.

(iii) Formats and Quizzes

There was no interaction between format and time of administering the quiz. The eta squared value (Table 5.10) indicates that together they can explain only 0.2 % of the total variance in scores.

MULTIPLE INTELLIGENCE STRENGTHS AND LEARNING

Learning Level Categories

For each subject the Δ quiz score (post-quiz score – pre-quiz score) was determined for all three protocols and identified by format. The Δ quiz scores were used as a measure of extent of learning in that format. The scores for each individual were compared and categorized in the following levels of learning: high, 3; moderate, 2; low, 1. Twenty-seven subjects who performed equally in more than one format were not included, leaving 292 subjects for whom extent of learning was categorized.

Intelligence Strength Categories

Shearer's five levels of intelligence strengths were reclassified into three categories – high, moderate and low – by combining very high and high in one category and low and very low in another category (Table 5.11). The linguistic, spatial, and logical-mathematical intelligence strength measurements for each subject were identified as high, 3; moderate, 2; or low, 1.

Intelligence Strength and Learning Format

The above designations of intelligence strength categories are used in Table 5.12 where it is seen that for each type of intelligence, subjects for the most part learned similarly from the formats whether they had high, moderate or low strength in the corresponding intelligence. This is supported by Table 5.13 which shows that very weak correlations exist between learning from any of the formats and intelligence strength, and that they are not significant at the 2-tailed significance level of $\alpha = 0.01$ level. Similarly, Figures 5.12, 5.13 and 5.14 show no differentiation in amount of learning according to tutorial format.

Learning through Primary Intelligence

Of the 319 subjects, 159 had higher strength in one intelligence (primary intelligence) than in the other two (secondary and tertiary intelligences), as measured by the MIDAS. When the mean amount of learning experienced in the primary intelligence was compared with the average means of learning in the secondary and tertiary intelligences (Tables 5.14) there was no significant difference significant at the 2-tailed significance level of $\alpha = 0.01$ and the

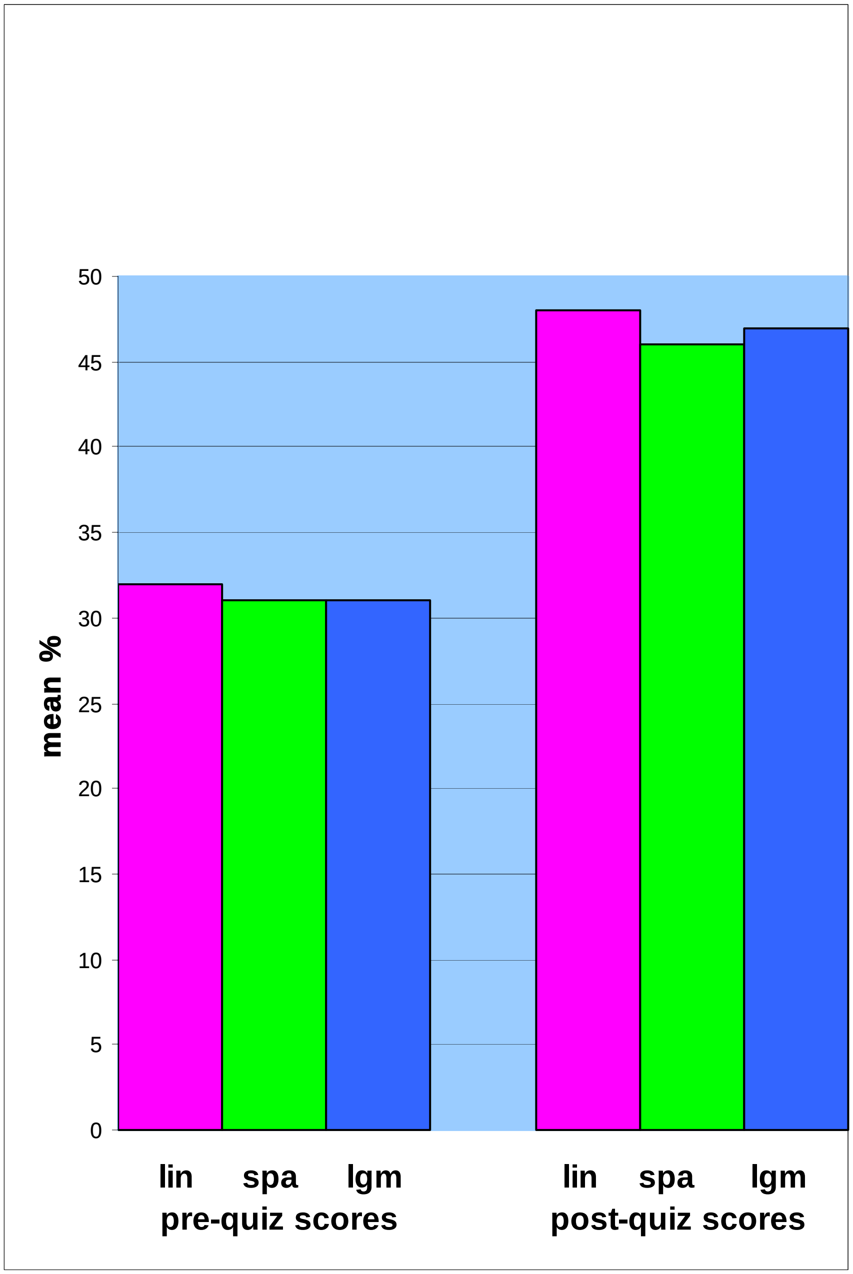


Figure 5.11: Mean Percent Quiz Scores With Respect to Presentation Formats

Table 5.11: Level Designations for Intelligences

Shearer's MIDAS Levels	Intelligence Categories
Very high (5) High (4)	High (3)
Moderate (3)	Moderate (2)
Low (2) Very Low (1)	Low (1)

Table 5.12: Number of Subjects Learning by Tutorial Formats for Each Intelligence

Intelligence Level	Learning By Linguistic Format			Learning By Spatial Format			Learning By Logical-mathematical Format		
	High	Mod-erate	Low	High	Mod-erate	Low	High	Mod-erate	Low
Linguistic									
High	36	34	31	34	31	34	30	34	36
Moderate	45	49	36	37	46	49	49	37	46
Low	20	25	16	23	15	23	18	21	22
Spatial									
High	37	42	26	35	31	39	33	32	40
Moderate	43	42	31	33	41	42	40	33	43
Low	21	24	26	26	20	25	24	27	20
Logical-mathematical									
High	45	43	31	40	38	41	34	38	47
Moderate	42	46	36	39	41	45	44	38	43
Low	14	19	16	15	13	20	19	16	13

Table 5.13: Correlations between Learning Formats and Intelligences

Learning Format	Intelligences		
	Linguistic	Spatial	Logical-mathematical
Linguistic	.01	.03	.01
Spatial	.01	.03	.04
Logical-mathematical	-.05	-.02	-.06

N = 319

None of these correlations was significant

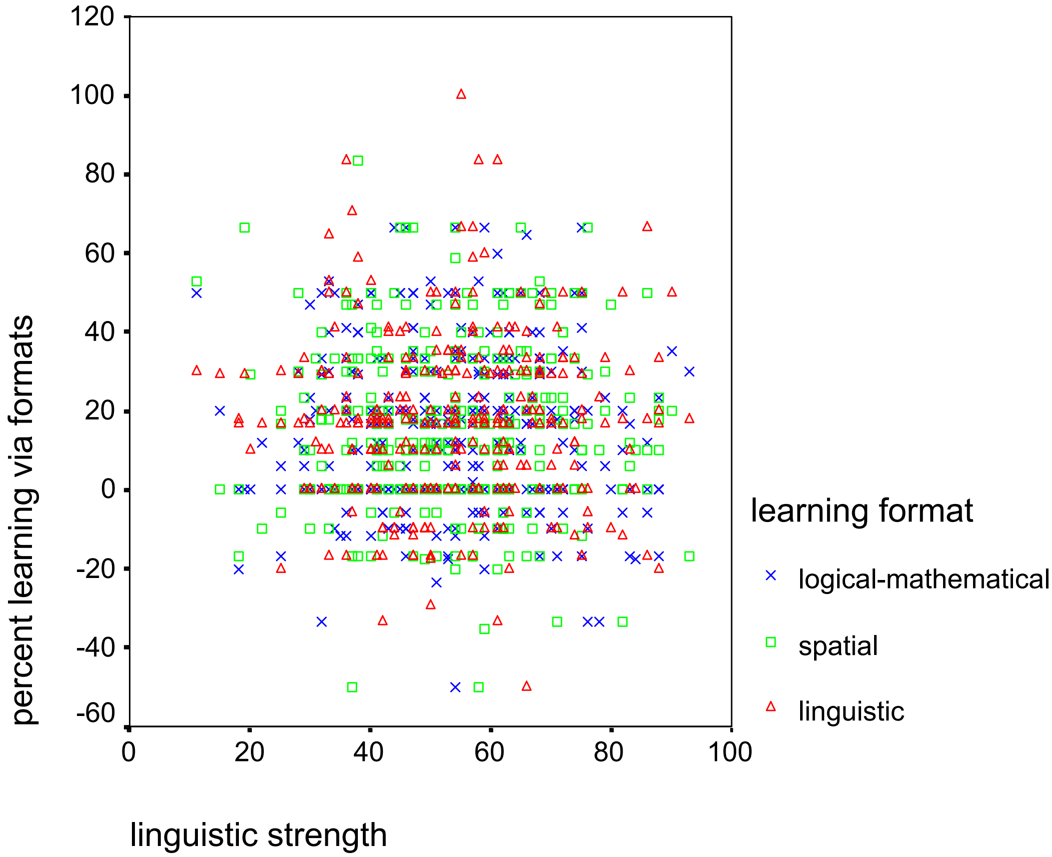


Figure 5.12: Dependence of Learning Formats on Linguistic Intelligence

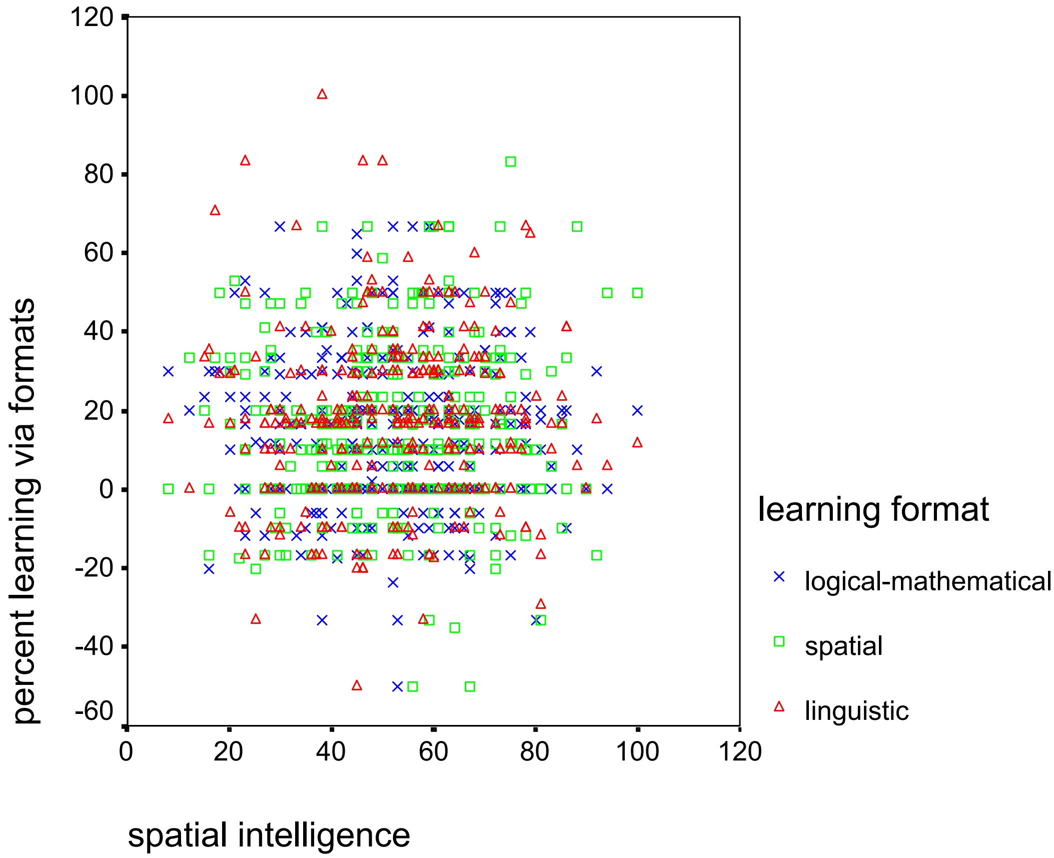


Figure 5.13: Dependence of Learning Formats on Spatial Intelligence

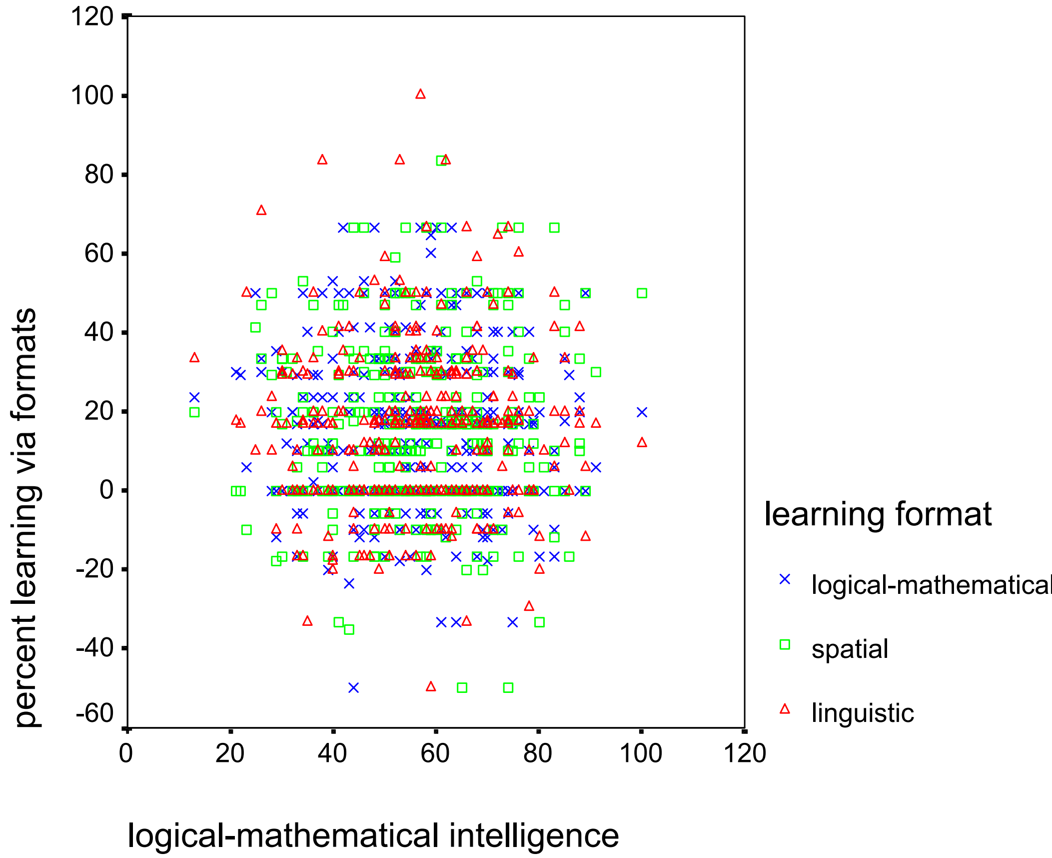


Figure 5.14: Dependence of Learning Formats on Logical-Mathematical Intelligence

Table 5.14: Comparison of Learning via Primary Intelligence and Learning via Other Intelligences

Learning Score Pair	Mean	Std. Dev.	Mean Diff.	Std. Error of Mean Diff.	t-value[1]	95% Confidence Interval
Via 1^0 intelligence	13.40	20.73				
Via 2^0 and 3^0 intelligences	15.34	13.85	-1.94	1.91	-1.012$^{n.s.}$	-2.03 4.35

[1]df = 158

n.s. = not significant at the $p < .05$ level

correlation between them was weak (r = .07) and not significant at the 2-tailed significance level of α = 0.05.

Subjects with Different Intelligence Strengths

Only fifty-one of the 319 subjects did not have similar linguistic, spatial and logical-mathematical intelligence strengths. Of these, 26 had some intelligences at high strengths and some intelligence at low strengths, and 25 had the three intelligences at high, moderate and low strengths. Table 5.15 shows that logical-mathematical intelligence predominated, followed by linguistic and lastly spatial. The amounts of learning that occurred for the formats corresponding to the primary (14.12), secondary (14.08) and tertiary (15.69) intelligences for these subjects did not differ significantly at the 2-tailed significance level of α = 0.05. The only significant correlation (r = .465, $p < .05$) was between performances via formats corresponding to the primary and tertiary intelligence.

Table 5.15: Distribution of Primary Secondary and Tertiary Intelligence Strengths of Subjects with Different Linguistic, Spatial and Logical-Mathematical Intelligence Strengths

Intelligence	Intelligence Strengths		
	Primary	Secondary	Tertiary
Linguistic	10	7	9
Spatial	6	3	17
Logical-mathematical	10	16	0

CHAPTER VI

DISCUSSION

This research was undertaken with the objective of investigating whether Howard's Gardner's theory of Multiple Intelligences could be used to differentiate between learners in a first-semester college chemistry course, and in so doing, to optimize their learning. The three intelligences identified by Gardner as necessary for learning in the physical sciences – linguistic, spatial and logical-mathematical – were chosen, and the topics Mole Concept, Chemical Bonding and Gas Laws were used for the learning experiences.

PILOT STUDY: GRADUATE STUDENTS

Intelligence Strengths

(i) Overall

Graduate students in the Department of Chemistry and Biochemistry were chosen as representative of persons who had attained a level of expertise in chemistry to be designated successful. Their MIDAS profiles showed them to possess high and average levels in all the intelligences and of these they showed high levels of logical-mathematical and intra-personal intelligences. Next in strength were their linguistic and spatial intelligences. These characteristics reflect the fact that prerequisites for admission into the chemistry department of the University of Texas as a graduate student include high scores on the verbal and quantitative Graduate Record Examinations (GRE).

(ii) By Divisions

It was also observed that, with the exception of the inorganic division which was represented by only one student, all the divisions were highest in linguistic but differed in relative logical-mathematical and spatial intelligences. Analytical and physical chemists were highest in logical-mathematical intelligences and biochemistry, chemical education and organic divisions were stronger in spatial intelligences. These results reflect the skills strongly needed by analytical chemists, organic chemists, physical chemists and biochemists.

Intra-personal Intelligence

Intra-personal intelligence surfaced as an important characteristic possessed by successful chemists. The ability to ask one's self the appropriate questions when seeking to understand a concept or to solve a problem is of utmost importance. The importance of intra-personal intelligence to the chemist is seen in its significant correlation with linguistic and logical-mathematical intelligences. It is also the only intelligence that is significantly correlated with any of the chemistry formats. It is therefore important that deliberate efforts be made to help beginning chemistry students develop their metacognative abilities.

Explanations

The explanations offered by the graduate students for their choices among the three formats showed that these students are at different levels of maturity as chemists. Some seemed to be thinking at the level of recall or were unwilling to investigate what seemed to be an unfamiliar format or one which seemed to require close investigation. More mature responses showed that some reflection of the possible formats had occurred. The transformation of a chemistry major from novice chemist to expert should make an interesting and instructive study.

THE EXPERIMENT: UNDERGRADUATE STUDENTS

Measuring Learning

Learning is a complex process that involves several contributing factors, some of which have been identified and many are yet to be identified. Thus, measuring learning continues to be a challenge, in spite of the several and varied testing methods that are practiced. Bearing in mind our limited ability to measure learning, the decision was made to use a series of multiple choice questions in a pre-quiz post-quiz combination. This was based on the ease of scoring student responses and the fact that students were used to this format of testing.

Efforts were made to minimize the number of uncontrolled variables by having identical pre-and post-quizzes given immediately before and after the intervention (tutorial). Possible interfering factors were distraction, fatigue or disinterest on the part of subjects as they went through the tutorial. The number of questions varied on the quizzes for the three topics (Mole Concept 6, Chemical Bonding 10, Gas Laws 17) because the emphasis was on covering all the concepts presented in the tutorials without being redundant. All scores were normalized as percentages. Efforts were also made to include questions which accommodated both algorithmic and conceptual thinking.

The Mole Concept quiz was the only one where persons scored 100 %, which suggests that it was not challenging enough and was unable to measure learning in those students who had full marks for both pre- and post quizzes.

Although most subjects' scores increased after the tutorial, there were several who had identical scores or even lower scores, thus giving zero or negative values for amount of learning. In many of these cases questions which were correctly answered on the pre-quiz were incorrectly answered on the post-quiz. This could have been due to guessing or to true misunderstanding of a concept or to not caring enough to make an honest effort.

Frequency Distribution

All measured data were found to be normally distributed and the statistical analyses applied were deemed appropriate.

Multiple Intelligences and Learning

(1) Intelligences

The intelligence profiles were derived from the MIDAS which is a self-reporting instrument, and so in making comparisons of the intelligences within-subjects rather than between-subject analyses were appropriate.

The relative strengths of the undergraduates and the graduate students differed. For the graduate students linguistic intelligence was highest and logical-mathematical and spatial intelligences were of similar strength whereas for the undergraduates logical-mathematical intelligence was greatest and linguistic and spatial were similar. It could be that the undergraduate students are still in the algorithmic mode of processing chemistry whereas the graduate students are stronger at the conceptual level. However, most of the undergraduate students had similar strengths in all three intelligences and only a small fraction could be characterized in terms of one strongest intelligence (Null hypothesis 1.) We cannot reject the first null hypothesis.

(ii) Amount of Learning

Paired samples t-tests and repeated measures analyses showed that the amount of learning that took place was not determined by tutorial format. The pre- and post-quiz scores indicate that the tutorials contributed to learning by the students, regardless of the tutorial format (Null hypothesis 2.) Similarly, multiple intelligence profile was not a determinant for the amount of learning that occurred (Null hypothesis 3.) Even in cases where a primary intelligence could be identified, it did not determine learning (Null hypothesis 4.) We cannot reject the second, third and fourth null hypotheses.

In the context of Gardner's theory, a plausible explanation is that since students have similar strengths of all three intelligences they are able to use any one intelligence, or a combination of intelligences, in learning. Their previous experiences in learning chemistry would have would have given them an introduction to the intelligences needed to learn chemistry.

Other Effects

In the absence of significant effect of presentation format or multiple intelligence profile on learning, other possible determinant variables were investigated.

(i) Pre-quiz Scores

In every case pre-quiz score was a significant ($p < .05$) determinant of post-quiz score, accounting for approximately 60 % of total variance in learning, whether differences in quiz formats or intelligences was considered. This means that prior knowledge is a strong predictor of performance, a finding consistent with the literature.

Multiple linear regression analyses (Table 6.1) that included other identifiable variables as possible determinants for post-quiz scores indicated from the R-squared values (Model 2) that the pre-quiz score for Mole Concept can explain 16 % of the variance in performance on the Mole Concept post-quiz; that pre-quiz score for Chemical Bonding can explain 22 % of the variance in performance on the Chemical Bonding post-quiz; and that pre-quiz score for Gas Laws can explain 13 % of the variance in performance on the Gas Laws post-quiz.

The ANOVA models 2, 3, and 4 which include pre-quiz scores indicate that pre-quiz scores made significant ($p < .05$) contributions to the variance. The relative regression values indicate that by considering the effect of pre-quiz score 15 % of performance in Mole Concept, 23 % of performance in Chemical

Table 6.1: ANOVA Models Showing Effects of Variables on Post-Quiz Scores

Concept	Model	F	Sig.	R^2	Adjusted R^2	R^2 Change	F Change	Sig. F Change
Mole Concept	1[a]	2.51	.06[a]	.02	.01	.02	2.51	.06
	2[b]	14.96	.00[b]	.16	.15	.14	51.11	.00
	3[c]	5.81	.00[c]	.19	.15	.03	1.20	.30
	4[d]	5.02	.00[d]	.19	.15	.00	.39	.68
Chemical Bonding	1[a]	1.65	.18[a]	.02	.01	.02	1.65	.18
	2[b]	23.47	.00[b]	.23	.22	.21	87.57	.00
	3[c]	8.48	.00[c]	.25	.22	.02	.99	.45
	4[d]	6.24	.00[d]	.25	.22	.00	.09	.92
Gas Laws	1[a]	.95	.42[a]	.01	.00	.01	.95	.42
	2[b]	11.79	.00[b]	.13	.12	.12	43.92	.00
	3[c]	5.21	.00[c]	.17	.14	.04	1.81	.08
	4[d]	5.65	.00[d]	.21	.17	.04	7.02	.00

a. Predictors: (Constant), logical-mathematical intelligence, linguistic intelligence, spatial intelligence
b. Predictors: (Constant), logical-mathematical intelligence, linguistic intelligence, spatial intelligence, pre-quiz
c. Predictors: (Constant), logical-mathematical intelligence, linguistic intelligence, spatial intelligence, pre-quiz, class lecturers
d. Predictors: (Constant), logical-mathematical intelligence, linguistic intelligence, spatial intelligence, pre-quiz, class lecturers, semester/session
e. Dependent Variable: post-quiz

Bonding and 12 % of performance in Gas Laws can be explained. In these models the coefficients for pre-quiz range between .30 and .47 ($p < .05$), with collinearity tolerance of .94 or greater, reflecting the fact that the variance they explain are not explained by other variables.

(ii) Concept

It was found (Table 6.2) that learning of the different concepts varied, with the greatest learning occurring with Mole Concept (17.55) and the least learning occurring with Chemical Bonding (12.63). Table 6.2 shows significant difference ($p < .05$) in the learning of Chemical Bonding compared to the learning of Mole Concept or Gas Laws but no significant difference at the significance level of $\alpha = 0.05$ between learning Mole Concept and Gas Laws. Correlation was very low (Table 6.3) between performances in the concepts. This fact and the lower measured learning for Chemical Bonding indicate that students found the topic of Chemical Bonding more challenging. This is graphically displayed in Figure 6.1 where it can be seen that performance on Mole Concept (MC) pre-quiz and post-quiz are much higher than performance on pre-quiz and post-quiz for the other concepts. Pre-quiz performance was similar for Chemical Bonding (CB) and Gas Laws (GL) but students had greater improvement with Gas Laws than with Chemical Bonding.

Mauchly's test (Table 6.4) indicates that sphericity cannot be assumed ($p < .05$) and variances (concept) and covariance (concept x time) are not similar across time (pre- and post-quizzes) and so Pillai's Trace and Wilk's

Table 6.2: Comparison of Extent of Learning of Tutorial Concepts

Concept Pair	Mean	Std. Dev.	Mean Diff.	Std. Error of Mean Diff.	t-value[1]	95% Confidence Interval	
Mole Concept Chemical Bonding	17.55 12.63	26.17 15.90	4.92	1.68	2.94*	1.63	8.22
Mole Concept Gas Laws	17.55 16.73	26.17 18.50	.83	1.78	.47 n.s.	-2.67	4.33
Chemical Bonding Gas Laws	12.63 16.73	15.90 18.50	-4.09	1.29	3.18*	1.56	6.63

[1]df = 318

n.s. = not significant at the $p < .05$ level

*$p < .05$

Table 6.3: Correlations between Learning of Tutorial Concepts

	Mole Concept	Chemical Bonding	Gas Laws
Mole Concept			
Chemical Bonding	$.05^{n.s}$		
Gas Laws	$.02^{n.s}$	.11*	

N = 319
n.s. = not significant at the *p* < .05 level
**p* < .05

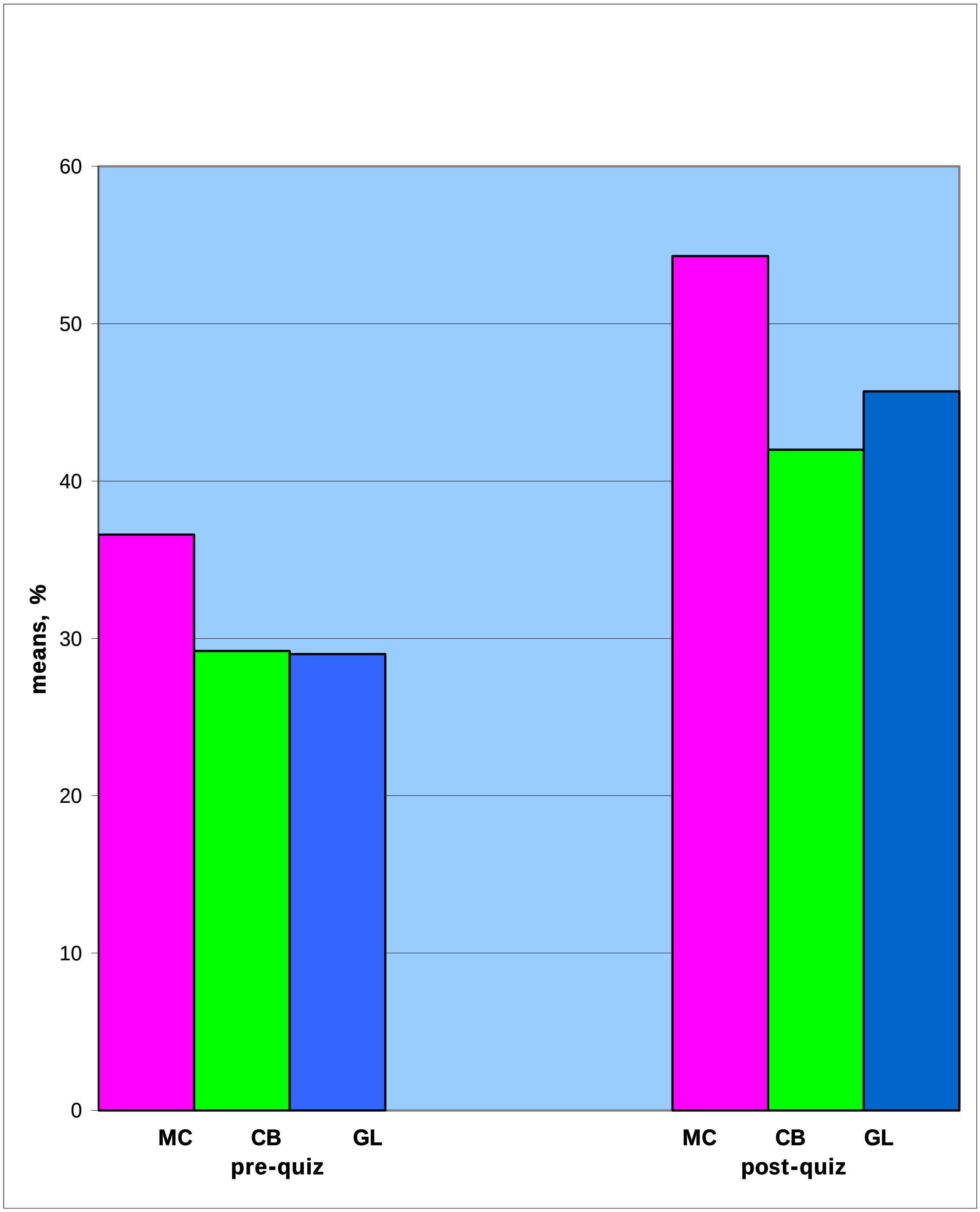


Figure 6.1: Mean Percent Quiz Scores With Respect to Concepts

Table 6.4: Mauchly's Test of Sphericity for Tutorial Concept[a]

Within-Subject Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
CONCEPT	.92	27.53	2	.00
TIME	1.00	.00	0	
CONCEPT * TIME	.88	41.78	2	.00

[a]Design: Intercept
Within Subjects Design: CONCEPT +TIME+ CONCEPT * TIME

Lambda (Table 6.5) were used to obtain eta squared values ($p < .05$) which indicate that tutorial concept can explain 20 % of the total variance in post-quiz scores ($p < .05$).

(iii) Class Teacher

The identity of the class teacher (Model 3) did not affect performance on post-quiz. Table 6.1 indicates no significant change in R squared for any of the concepts at the significance level of $\alpha = 0.05$.

(iv) Semester

With the exception of the concept Gas Laws (Table 6.1), the semester/session that the experiment was done (Model 4) did not turn out to be a significant predictor of post-quiz performance at the significance level of $\alpha = 0.05$. The small change in F and small regression value (Table 6.1,) indicates that where it is significant ($p < .05$) the effect of semester/summer on the topic Gas Laws is negligible.

Subject Preference

Feedback solicited from the subjects after each experimental session is supportive of the overall experimental results. Table 6.6 summarizes the percent of respondents making each choice on a 5-point Likert scale and reflects an overall positive response to their experiences. It can be seen that their responses to the different formats vary very little, unlike their responses to the different concepts where they favor Mole Concept most and Chemical

Table 6.5: Multivariate Tests[b] of Significance for Tutorial Concept

Within-Subject Effect	Value	F	Hypothesis df	Error df	Sig.	Eta Squared
CONCEPT						
Pillai's Trace	.20	40.94[a]	2.00	317.00	.00	.20
Wilk's Lambda's Trace	.80	40.94[a]	2.00	317.00	.00	.20
TIME						
Pillai's Trace	.61	503.69[a]	1.00	318.00	.00	.61
Wilk's Lambda's Trace	.39	503.69[a]	1.00	318.00	.00	.61
CONCEPT * TIME						
Pillai's Trace	.04	6.73[a]	2.00	317.00	.00	.04
Wilk's Lambda's Trace	.96	6.73[a]	2.00	317.00	.00	.04

[a]Exact statistic
[b]Design: Intercept
Within Subjects Design: CONCEPT +TIME+ CONCEPT * TIME

Table 6.6: Relative Preferences of Subjects for Format and Concept

		LIKERT SCALE*				
		5	4	3	2	1
FORMAT	Linguistic	32.5	31.1	21.9	10.3	4.1
	Spatial	31.9	31.6	22.6	10.7	3.2
	Logical-mathematical	33.9	29.6	23.0	10.2	3.4
CONCEPT	Mole Concept	46.4	15.3	24.9	10.4	3.0
	Chemical Bonding	26.8	29.0	25.8	13.2	5.1
	Gas Laws	33.5	30.5	22.4	10.2	3.4

*5 very positive, 1 very negative

Bonding least. One hundred and eight of the students who participated in the experiment during the Summer 2003 sessions and who also responded to all the items on the evaluation sheet indicated no significant differences in format preference at the significance level of $\alpha = 0.05$ (Table 6.7). These format preferences showed a small significant correlation (Table 6.8) between pairs of preferences, the greatest being between linguistic and spatial, the smallest between spatial and logical-mathematical; this order is opposite from the order of correlation between the intelligences (Table 5.3).

When the preferences of the summer subjects for format was compared with extent of learning (Table 6.9) very low and non-significant correlation with format was seen at the significance level of $\alpha = 0.05$.

Implications of Results

This study was done using tutorials in formats that correspond to the intelligences identified as needed for learning chemistry and which are typically used, though to varying degrees, by chemistry instructors. The results indicate that in first-year college chemistry students have linguistic, spatial and logical-mathematical intelligences at similar strengths and that there are no significant differences between the means of their linguistic, spatial and logical-mathematical intelligences. The results also indicate no significant difference between the extent to which they learn from formats corresponding to linguistic, spatial and logical-mathematical intelligences and that their learning is not determined by their primary intelligences. For the most part, first-semester

Table 6.7: Comparison of Summer Subjects' Preferences for Tutorial Formats

Concept Pair	Mean	Std. Dev.	Mean Diff.	Std. Error of Mean Diff.	t-value[1]	95% Confidence Interval	
Linguistic Spatial	41.85 42.18	6.95 7.05	-.32	.75	-.43[n.s.]	-1.81	1.16
Linguistic Logical-mathematical	41.85 42.41	6.95 7.22	-.56	.81	-.68[n.s.]	-2.17	1.06
Spatial Logical-mathematical	42.18 42.41	7.05 7.22	-.23	.83	-.28[n.s.]	-1.87	1.41

[1]df = 107

n.s. = not significant at the $p < .05$ level

Table 6.8: Correlations between Preferences of Summer Subjects for Tutorial Formats

	Linguistic	Spatial	Logical-mathematical
Linguistic			
Spatial	.38*		
Logical-mathematical	.29*	.28*	

N = 108

**p* < .05

Table 6.9: Correlations between Preferences of Summer Subjects for Format and Extent of Learning via Format

Format Preference	Extent of Learning from Format		
	Linguistic	Spatial	Logical-mathematical
Linguistic	.06	-.04	-.14
Spatial	.09	.01	-.05
Logical-mathematical	-.12	.06	-.04

N = 108

None of these correlations was significant

chemistry students have adapted to all three presentation formats and are able to learn from them in a similar fashion. This fact should be encouraging to educators who are endeavoring to use all these formats in presenting chemistry concepts.

Recommendation for Further Study

The experiences of chemistry educators like Lerman (50), Brown Wright (52), and Sweet (99), indicate that for some students learning in chemistry is facilitated by presenting concepts in unusual formats. Gardner's challenge that "any topic worth teaching can be approached in five difference ways" is an open invitation to chemical education researchers to investigate intelligences other than linguistic, spatial and logical-mathematical in the learning of chemistry. The multiple intelligence profiles of the chemistry graduate students indicated that kinesthetic and intra-personal intelligences are significantly correlated with the intelligences already identified as important in learning chemistry. These would be good candidates for the next investigation into the applicability of Howard Gardner's theory to the learning of chemistry.

Experiments that explore the effect of presenting chemistry via the multiple intelligences identified by Gardner could serve to advance knowledge about how to make chemistry more learner-friendly to non-science persons, thus aiding chemistry educators in their progress toward a key objective, that of developing a scientifically literate society.

APPENDIX A

IRB Approval for Pilot Study

THE UNIVERSITY OF TEXAS AT AUSTIN

Application for the Review of a Project Involving Human Subjects

APPLICATION FOR DRC REVIEW ONLY (EXEMPT FROM IRB REVIEW)

Project Title: THE RELATIONSHIP BETWEEN MULTIPLE INTELLIGENCES AND THE LEARNING OF CHEMISTRY CONCEPTS

Principal Investigator(s): (Give address for correspondence about approval. Student PIs may prefer to list a home address rather than a departmental address.)

GLORIA A. BROWN WRIGHT	CHEMISTRY and BIOCHEMISTRY A5300	glo.brownwr@mail.utexas.edu
(Name - type or print)	(Department and Campus Mail Code)	E-mail Address

Faculty Supervisor (if PI is a student):

Dr. J. J. Lagowski	CHEMISTRY and BIOCHEMISTRY A5300	jjl@mail.utexas.edu
(Name - type or print)	(Department and Campus Mail Code)	E-mail Address

If the project is a student project, attach the Faculty Supervisor Approval Form.

If funded or submitted for funding: Agency or source of funding N/A

Title of grant: N/A

Grant contract number (if known): N/A

Exemption Category: 45 CFR 46.101 (b) 1, 2. (See Criteria for Exemption from IRB Review and Exemption Categories.)

In making this application, I certify that I understand the policies and procedures governing research with human subjects developed by The University of Texas at Austin and that I fully intend to comply with the letter and spirit of The University's Multiple Project Assurance (MPA). I further acknowledge my responsibility to report any changes in the protocol and to obtain written approval for these changes prior to making them. Copies of the Policies and Procedures Manual, the MPA, and 45 CFR 46 have been distributed to DRCs and are also available in OSP. **Continuing Review Requirements:** Annual DRC review and continuing DRC and IRB surveillance must be maintained for compliance with DHHS policies and The University's MPA.

Signature(s): Principal Investigator(s) and Faculty Supervisor (if student project) — 20/Sept 2000 Date

Reviewed and Approved by Departmental Review Committee:

Dr. Holcombe — 9/22/00

Signature of DRC Chair — Date

If funding is being sought, send one original signed and approved application to OSP, MAI 303, F3900. (See the reverse side of this page for the components of an application.) If no funding is sought, the signed and approved application should be kept on file by the DRC for three years. If the investigator's department does not have a DRC, the application will be reviewed by the IRB chair and kept on file at OSP.

Revised 9/00

Exempt Application

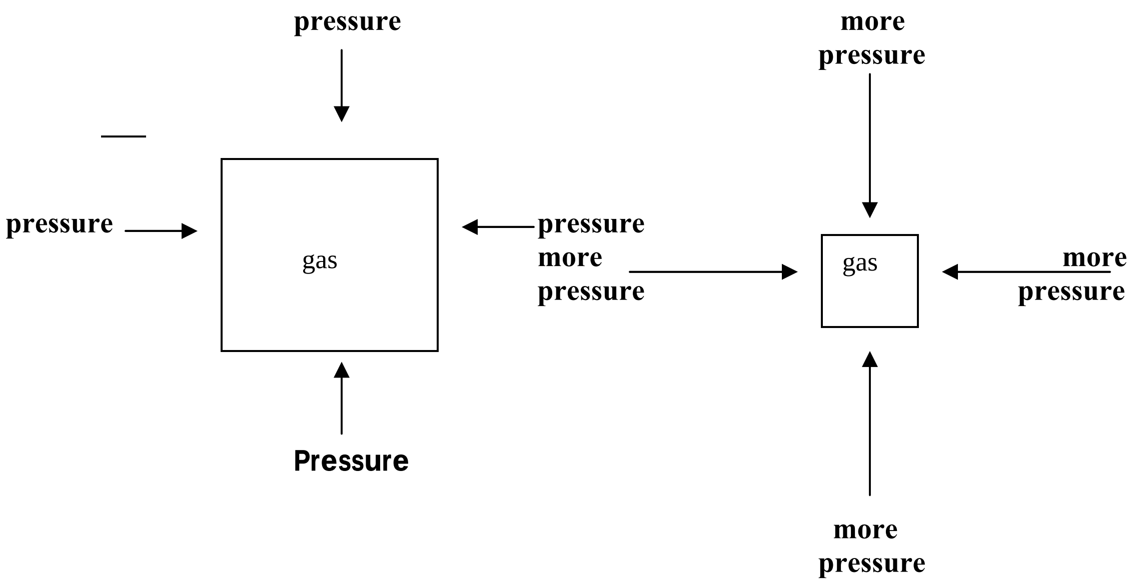
APPENDIX B

Sample Questions from Chemistry Instrument for Pilot Study

TOPIC: Gases
STATEMENT: A sample of gas contracts (volume decreases) when the pressure on it increases because
EXPLANATIONS:

___ **P is indirectly proportional to V (P α 1/V).**
___ **putting more pressure on the gas squeezes it into a smaller space.**

___

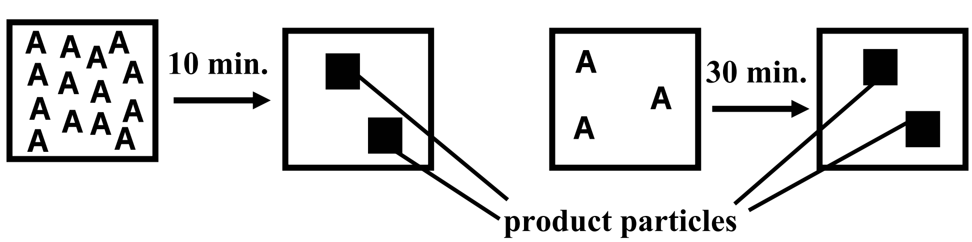


TOPIC: Kinetics
STATEMENT: The principle that "a reaction occurs in less time when more of the reactant is present" is observed for the reaction "A → product" in
EXAMPLES:

___ **the equation 1/t = k[A], where t is time, k is a constant, [A] is concentration of A.**

___ **the fact that when more of reactant A is present the reaction goes faster.**

___



TOPIC: Limiting Reagents

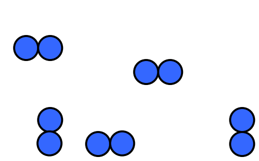
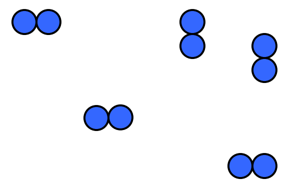
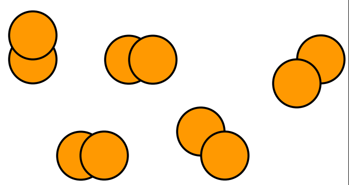
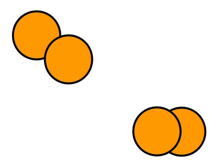
STATEMENT: **Given the balanced equation for the reaction I which dinitrogen pentoxide is made from its elements:**

$$2N_2 + 5O_2 \longrightarrow 2N_2O_5,$$

when 5 moles of each reactant are available for the reaction, the limiting reagent is oxygen because

EXPLANATIONS:

___

	HAVE	**NEED**
Oxygen molecules		
Nitrogen molecules		

__ **mol N_2/ O_2 present = 5/5 = 1**

mol N_2/ O_2 needed = 2/5

___ **We have an equal number of moles of nitrogen and oxygen present but the reaction requires that we have two parts nitrogen to five parts oxygen.**

APPENDIX C

Sample Questions from the MIDAS

MUSICAL

4. Do you have a good voice for singing with other people in harmony?
   A=a little bit; B=fair; C=good; D=very good; E=excellent; F=I don't know

5. Did you ever play an instrument, play with a band or sing with a group?
   A=never; B=every once in a while; C=sometimes; D=often; E=almost all the time;
   F=I don't know. Does not apply

BODILY-KINESTHETIC

21. Do you often do physical work or exercise?
    A=rarely; B=sometimes; C=often; D=almost all the time; E=all the time;
    F=I don'tknow. Does not apply

22. Are you good with your hands at things like card shuffling, magic tricks or juggling?
    A=not very good; B=fair; C=good; D=very good; E=excellent; F=I don't know

VISUAL-SPATIAL

48. Can you parallel park a car on your first try?
    A=rarely or do not drive; B=sometimes; C=often; D=almost all the time;
    E=all the time; F=I don't know. Does not apply

49. Are you good at finding your way around new buildings or city streets?
    A=not at all; B=fairly good; C=good; D=very good; E=excellent; F=I don't know

LOGICAL-MATHEMATICAL

34. Do you often play games such as Scrabble or crossword puzzles?
    A=very rarely or never; B=every once in a while; C=sometimes; D=often;
    E=all the time; F=I don't know

35. Do you have a good system for managing your money or figuring a budget?
    A=not at all; B=fairly good; C=good; D=very good; E=an excellent system;
    F=I don't know or does not apply

LINGUISTIC-VERBAL

62. Do you use colorful words or phrases when talking?
    A=no; B=rarely; C=sometimes; D=often; E=all the time; F=I don't know

63. Have you ever written a story, poetry or words to songs?
    A=never; B=maybe once or twice; C=occasionally; D=often; E=almost all the time;
    F=I don't know

INTERPERSONAL

81. Are you good at making peace at home, at work or among friends?
A=fair; B=pretty good; C=good; D=very good; E=excellent; F=I don't know

82. Are you ever a 'leader' for doing things at school, among friends or at work?
A=rarely; B=every once in a while; C=sometimes; D=often; E=almost always; F=I don't know

INTRAPERSONAL

99. Are you aware of your feelings and able to control your moods?
A=every once in a while; B=sometimes; C=most of the time; D=almost all the time; E=always; F=I don't know

100. Do you plan and work hard toward personal goals like at school, at work or at home?
A=rarely; B=sometimes; C=usually; D=almost all the time; E=all the time; F=I don't know

NATURALIST

112. Are you good at recognizing breeds of pets or kinds of animals?
A=not at all; B=at little; C=somewhat; D=quite good; E=very good; F=I don't know

113. Are you good at observing and learning about nature, for example, types of clouds, weather patterns, animal or plant life?
A=never; B=a little; C=some; D=quite a bit; E=a great deal; F= I don't know

EXISTENTIAL (proposed)

(An assessment for the proposed existential intelligence has been created and is currently being validated. If you would like to participate in this project please send a research application and describe what you would like to do.)

8. Do you spend time in prayer, meditation or just thinking about life?
0=never; 1=every once in a while; 2=sometimes; 3=often; 4=all the time; X=I don't know

9. Do you discuss or ask questions to probe deeply into the meaning of human life?
0=never; 1=rarely; 2=every once in a while; 3=sometimes; 4=often; X=I'm not sure

APPENDIX D

Interview Questions for Graduate Students

Introduction: The purpose of this interview is to get feedback from you on your impressions of the survey.

1. Were you able to recognise that the questions represented the three intelligences, linguistic, spatial and logical-mathematical?

2. How would you characterise your relative strengths in those three intelligences?
   Is this a realisation that came out of your doing the instrument, or were you aware of this before.

3. About how long did it take you to do the survey? Demographics? Chemistry?

4. This is a paper copy of the instrument. I'll remind you of the rankings you made, and I'm going to ask you to explain why you assigned those ranks. Also, please make any other observations/comments you think are relevant.

Thank you very much for taking part.

APPENDIX E

Instructions Sheet for Graduate Students

1. For NAME put your name.

2. For BIRTH DATE put the date you do the MIDAS.

3. For IDENTIFICATION NUMBER, columns A, C, E and G:
   in column A (0 to 6) put your division as follows:
   - 0 for undecided
   - 1 for analytical
   - 2 for biochemistry
   - 3 for chemical education
   - 4 for inorganic
   - 5 for organic
   - 6 for physical

   in column C (1 to 9) put your year as a graduate student. Bubble in 9 for year 9 or above.
   in column E (1 to 9) put your teaching experience in terms of semesters. Two summers may count as one semester. Bubble in 9 for 9 or more.
   in column G (1 to 9) put your research experience in terms of semesters. Two summers may count as one semester. Bubble in 9 for 9 or more.

4. For SPECIAL CODES, put your semester credits (2 semester credits = 3 quarter credits) of mathematics and physical sciences in columns K to P as follows: chemistry in columns K and L; mathematics in columns M and N; physics in columns O and P. [N.B. ug = undergraduate, g = graduate]

In the column, bubble	Chemistry		Mathematics		**Physics**	
	K (ug)	L (g)	M (ug)	N (g)	O (ug)	P (g)
0	< 24	0	0	0	0	0
1	24-27	1-6	1-3	1-3	1-3	1-3
2	28-31	7-12	4-6	4-6	4-6	4-6
3	32-35	13-18	7-9	7-9	7-9	7-9
4	36-39	19-24	10-12	10-12	10-12	10-12
5	40-43	25-28	13-15	13-15	13-15	13-15
6	44-47	29-32	16-18	16-18	16-18	16-18
7	48-50	33-36	19-21	19-21	19-21	19-21
8	51-52	37-40	22-24	22-24	22-24	22-24
9	> 52	>40	>24	>24	>24	>24

5. Return the instrument and the scantron to researcher.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION. YOU WILL BE GIVEN THE RESULTS AS SOON AS YOUR MULTIPLE INTELLIGENCES ARE PROFILED.

APPENDIX F

IRB Approval for Study with Undergraduate Students

OFFICE OF RESEARCH SUPPORT & COMPLIANCE

THE UNIVERSITY OF TEXAS AT AUSTIN

P. O. Box 7426, Austin, Texas 78713 (512) 471-8871 - FAX (512 471-8873)
North Office Building A, Suite 5.200 (Mail code A3200)

Date: **6/14/2002**

PI(s): **Joseph J Lagowski** Department & Mail Code: **CHEM & BIOCHEM DEPT A5300**
Gloria A Brown **CHEM & BIOCHEM DEPT A5300**

Dear: **Joseph J Lagowski** **Gloria A Brown**
IRB APPROVAL – IRB Protocol # **2002-06-0026**

Title: **Multiple Intelligences and the Learning of Chemistr: Is It Possible to Enhance the Learning of Chemistry by Accommodating the Learner's Multiple Intelligences?**

In accordance with Federal Regulations for review of research protocols, the Institutional Review Board has reviewed the DRC's exempt status assessment of the above referenced protocol and found that it meets Exempt Approval under the category designated below for the following period:

Your study has been approved from 06/13/2002 - 06/13/2003

Exempt Category of Approval:

1. [x] Research with non-minors involving normal educational practices in commonly accepted educational settings involving normal educational practices.

2. [ ] Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures, or the observation of public behavior so long as confidentiality is maintained. Exemption is not granted if BOTH the following occur: 1) subjects' responses can be identified; and 2) disclosure of the subjects' responses would place them at risk. For example, surveys on drug use, sexual behavior, alcohol use, etc., are not exempt. If the subjects are children, educational tests are exempt but not survey or interview procedures; observations of public behavior of children are exempt only if the investigator does not participate in the activities being observed.

3. [ ] Research involving the use of educational tests, survey or interview procedures, or observing public behavior that is not exempt under number 2 above, if the subjects are public officials or candidates for public office or a federal statute requires that the confidentiality of personally identifiable information will be maintained throughout the research and thereafter.

4. [ ] Research involving the collection or study of existing data, documents, records, pathological or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, either directly or through identifiers linked to the subjects. To qualify for this exemption, the data, documents, records or specimens must be in existence before the project begins.

5. [ ] Research and demonstration projects evaluating public benefit or service programs which have been approved by department or agency heads.

6. [ ] Taste and food quality evaluation and consumer acceptance studies, involving adults only.

RESPONSIBILITIES OF PRINCIPAL INVESTIGATOR FOR ONGOING PROTOCOLS:

(1) Report **immediately** to the IRB any severe adverse reaction or serious problem, whether anticipated or unanticipated.
(2) Report any significant findings that become known in the course of the research that might affect the willingness of subjects to continue to take part.
(3) Insure that only persons formally approved by the DRC enroll subjects.
(4) If relevant to your study, please use **only** a currently approved consent form (remember approval periods are for 12 months or less).
(5) **Protect the confidentiality of all personally identifiable information collected and train your staff and collaborators on policies and procedures for ensuring confidentiality of this information.**
(6) Submit for review and approval by the IRB all modifications to the protocol or consent form(s) prior to the implementation of the change.
(7) Please note that this office will send out a reminder prior to the end of your approval period (typically at the end of the 12 months). At this time we will ask you to give us an update on whether the study is still in progress and/or has had any changes that need to be reviewed for approval.
(8) Notify the IRB and the DRC when the study has been completed and complete the Final Report Form.
(9) Please help us help you by including the above protocol number on all future correspondence relating to this protocol.

Thank you for your help in this matter.

Sincerely,

Clarke Burnham, Ph.D., Chair
Institutional Review Board

cc: DRC

OFFICE OF RESEARCH SUPPORT & COMPLIANCE

THE UNIVERSITY OF TEXAS AT AUSTIN

P. O. Box 7426, Austin, Texas 78713 (512) 471-8871 - FAX (512 471-8873)
North Office Building A, Suite 5.200 (Mail code A3200)

Date: **4/16/2003**

PI(s): **Joseph J Lagowski**	Department & Mail Code:	**CHEM & BIOCHEM DEPT**	**A5300**
Gloria A Brown		**CHEM & BIOCHEM DEPT**	**A5300**

Dear: **Joseph J Lagowski** **Gloria A Brown**

IRB APPROVAL – IRB Protocol # **2002-06-0026**

Title: **Multiple Intelligences and the Learning of Chemistry: Is It Possible to Enhance the Learning of Chemistry by Accommodating the Learner's Multiple Intelligences?**

In accordance with Federal Regulations for review of research protocols, the research study listed above has been re-approved for the following period of time:

Your research study has been re-approved from 04/09/2003 – 04/09/2004

RESPONSIBILITIES OF PRINCIPAL INVESTIGATOR FOR ONGOING PROTOCOLS:

(1) Report **immediately** to the IRB any severe adverse reaction or serious problem, whether anticipated or unanticipated.
(2) Report any significant findings that become known in the course of the research that might affect the willingness of subjects to continue to take part.
(3) Insure that only persons formally approved by the IRB enroll subjects.
(4) Use **only** a currently approved consent form (remember approval periods are for 12 months or less).
(5) **Protect the confidentiality of all personally identifiable information collected and train your staff and collaborators on policies and procedures for ensuring confidentiality of this information.**
(6) Submit for review and approval by the IRB all modifications to the protocol or consent form(s) prior to the implementation of the change.
(7) Submit a **Continuing Review Report** for continuing review by the IRB. Federal regulations require **IRB review of on-going projects no less than once a year** (a Continuing Review Report form and reminder letter will be sent to you 2 months before your expiration date). Please note however, that if you do not receive a reminder from this office about your upcoming continuing review, it is the primary responsibility of the PI not to exceed the expiration date in collection of any information. Finally, it is the responsibility of the PI to submit the Continuing Review Report before the expiration period.
(8) Notify the IRB when the study has been completed and complete the Protocol Closure Report.
(9) Please help us help you by including the above protocol number on all future correspondence relating to this protocol.

Thank you for your help in this matter.

Sincerely,

Clarke Burnham, Ph.D., Chair
Institutional Review Board

cc: DRC

APPENDIX P

Mole Concept Pre-Quiz

The purpose of this pre-quiz is to measure your knowledge of the MOLE CONCEPT. Following the PRE-QUIZ you will have a tutorial on the MOLE CONCEPT, and then after the tutorial you will do a post-quiz to see how helpful the tutorial was for you

PRE-QUIZ on MOLE CONCEPT

For each pair of samples below, identify the sample which contains the larger number of the particles indicated.

[atomic weights: C = 12, Fe = 56, H = 1, O = 16, He = 4]

(a) (i) one mole of hydrogen molecules (H_2)
(ii) one mole of hydrogen atoms (H) (iii) neither

(b) (i) one mole of hydrogen (ii) one mole of electrons (iii) neither

(c) (i) one mole of hydrogen molecules (ii) one mole of iron (Fe) atoms
(iii) neither

(d) (i) one liter of carbon dioxide (CO_2) at S.T.P. (i) one liter of helium (He) at S.T.P. (iii) neither

(e) (i) one gram of carbon (ii) 4 grams of helium
(iii) neither

(f) (i) 4 mL of 2M aqueous ammonia (NH_3) (ii) 5 mL of 1M aqueous iodine (I_2)
(iii) neither

APPENDIX Q

Mole Concept Post-Quiz

POST-QUIZ on MOLE CONCEPT

For each pair of samples below, identify the sample which contains the larger number of the particles indicated.

[atomic weights: C = 12, Fe = 56, H = 1, O = 16, He = 4]

(a) (i) one mole of hydrogen molecules (H_2)
(ii) one mole of hydrogen atoms (H) (iii) neither

(b) (i) one mole of hydrogen (ii) one mole of electrons (iii) neither

(c) (i) one mole of hydrogen molecules (ii) one mole of iron (Fe) atoms
(iii) neither

(d) (i) one liter of carbon dioxide (CO_2) at S.T.P. (i) one liter of helium (He) at S.T.P. (iii) neither

(e) (i) one gram of carbon (ii) 4 grams of helium
(iii) neither

(f) (i) 4 mL of 2M aqueous ammonia (NH_3) (ii) 5 mL of 1M aqueous iodine (I_2)
(iii) neither

APPENDIX R

Chemical Bonding Pre-Quiz

IDENTITY: CD CODE:

PRE-QUIZ on CHEMICAL BONDING

There are ten (10) multiple choice questions. For each question, circle the letter which corresponds to the most appropriate response.

1. The part of the atom that is involved in chemical bonding is
   a. all the electrons
   b. the core electrons
   c. the nucleus
   d. the valence electrons
   e. the whole atom

2. The type of bonding in calcium oxide is called
   a. ionic
   b. nonpolar covalent
   c. polar covalent
   d. simple covalent

3. In ionic bonding, nonmetals
   a. gain electrons
   b. lose electrons
   c. share electrons
   d. none of the above

4. Covalent bonding occurs between
   a. metals
   b. metals and nonmetals
   c. nonmetals
   d. any two elements

5. Examples of polar molecules would NOT include [I F_2, II NO, III ClF_3, IV PF_5]
   a. I and III
   b. I, II and III
   c. I and IV
   d. I, II and IV
   e. II and III
   f. II, III and IV
   g. I, II, III and IV
   h. All are polar

6. Lewis structures which obey the Octet rule include
   a. $BeCl_2$
   b. ICl_2^+
   c. PCl_4^-
   d. SCl_4
   e. XeF_2

7. Triple covalent bonding is found in
   a. Br_2
   b. N_2
   c. NF_3
   d. O_3

8. The number of bonds in an octahedrally-shaped molecule is
   a. 4
   b. 6
   c. 8
   d. 10

9. The number of nonbonding electron pairs is two (2) in all of the following, EXCEPT
   a. H_2S
   b. IF_3
   c. SiL_4
   d. XeF_4

10. The shape of XeF is
    a. octahedral
    b. see-saw
    c. square planar
    d. square pyramid
    e. Tetrahedral
    f. T-shaped

APPENDIX S

Chemical Bonding Post-Quiz

IDENTITY: CD CODE:

POST-QUIZ on CHEMICAL BONDING

There are ten (10) multiple choice questions. For each question, circle the letter which corresponds to the most appropriate response.

1. The part of the atom that is involved in chemical bonding is
   a. all the electrons
   b. the core electrons
   c. the nucleus
   d. the valence electrons
   e. the whole atom

2. The type of bonding in calcium oxide is called
   a. ionic
   b. nonpolar covalent
   c. polar covalent
   d. simple covalent

3. In ionic bonding, nonmetals
   a. gain electrons
   b. lose electrons
   c. share electrons
   d. none of the above

4. Covalent bonding occurs between
   a. metals
   b. metals and nonmetals
   c. nonmetals
   d. any two elements

5. Examples of polar molecules would NOT include [I F_2, II NO, III ClF_3, IV PF_5]
   a. I and III
   b. I, II and III
   c. I and IV
   d. I, II and IV
   e. II and III
   f. II, III and IV
   g. I, II, III and IV
   h. All are polar

6. Lewis structures which obey the Octet rule include
   a. $BeCl_2$
   b. ICl_2^+
   c. PCl_4^-
   d. SCl_4
   e. XeF_2

7. Triple covalent bonding is found in
   a. Br_2
   b. N_2
   c. NF_3
   d. O_3

8. The number of bonds in an octahedrally-shaped molecule is
   a. 4
   b. 6
   c. 8
   d. 10

9. The number of nonbonding electron pairs is two (2) in all of the following, EXCEPT
   a. H_2S
   b. IF_3
   c. SiL_4
   d. XeF_4

10. The shape of XeF is
    a. octahedral
    b. see-saw
    c. square planar
    d. square pyramid
    e. Tetrahedral
    f. T-shaped

APPENDIX T
Gas Laws Pre-Quiz

R = 0.08205 L atm mol^{-1} K^{-1} = 62360 mL torr mol^{-1} K^{-1} K = 8.3144 pa m^3 mol^{-1} K^{-1}
Molar volume of a gas = 22.414 L/mol

IDENTITY: CD CODE:

Concept 3: <u>GAS LAWS*</u>

PRE-QUIZ

1. Complete the table below for each of the six cases, indicating the effect
(A: decrease/B: increase/C: unchanged)
on the fourth property of a gas under the conditions given for the other three properties. For example, in case 1 write "A" or "B" or "C" to indicate what happens to the volume of a fixed amount of gas when its pressure is kept constant while its temperature is decreased. In the sixth column, identify the relevant gas law for cases 1, 3, 4 and 5 by writing the Roman numeral which corresponds to the law:
(I: Avagadro's Law; II: Boyle's Law; III: Charles' Law;
IV: Dalton's Law; V: Gay-Lussac's Law; VI: Ideal Gas Law.)

CASE	AMOUNT	PRESSURE	TEMPERATURE	VOLUME	GAS LAW
1	unchanged	unchanged	decreased		
2	increased		unchanged	unchanged	[redacted]
3	unchanged	decreased		unchanged	
4	unchanged		unchanged	increased	
5		unchanged	unchanged	increased	

2. A gas, G, initially at a temperature of 27 ^{0}C and a pressure of 1.00 atmospheres is moved from a 25-mL gas jar to a 75-mL gas jar where its pressure becomes 380 torrs. Circle the letter which corresponds to the most appropriate response in each case below.

(i) The temperature of gas G in the 75-mL flask is now, in ^{0}C,
A -73 B 40.5 C 177 D 200 E 450 F 723 G 1800
H 342000

(ii) At 27 ^{0}C the number of moles of gas G in the sample is

A 8.33 x 10^{-5} B 0.00102 C 0.011 D 0.615 E 0.772 F 1.02
G 8.58 H 89 I 985 F Correct answer not shown
The gas law involved is ________. (Use the gas law list from question 1)

(iii) When the sample of gas G is warmed to 37 ^{0}C the number of moles of gas in the sample is
A decreased B increased C unchanged
D Insufficient information provided

(iv) At S.T.P. 1.60 g of gas G (40.0 g/mol) has a volume of
A 1.78 mL B 350 mL C 897 mL D 1.12 L E 2.86 L F 560 L
G 1434 L H Correct answer not shown

(v) If neon gas at a partial pressure of 200 torrs and krypton gas at a partial pressure of 17 torrs are at 4.00 K in a 100-mL gas jar, adding 0.3 moles of gas G would make the pressure in the gas jar (in torrs)
A 0.009846 B 0.9846 C 7.48 D 210 E 216 F 217
G 218 H 224 I 543 J 748 K 760 L 965
M Correct answer not shown
The gas laws involved are ______ and ______. (Use the gas law list from question 1)

APPENDIX U

Gas Laws Post-Quiz

R = 0.08205 L atm mol^{-1} K^{-1} = 62360 mL torr mol^{-1} K^{-1} K = 8.3144 pa m^3 mol^{-1} K^{-1}
Molar volume of a gas = 22.414 L/mol

IDENTITY: CD CODE:

Concept 3: GAS LAWS*

POST-QUIZ

1. Complete the table below for each of the six cases, indicating the effect (A: decrease/B: increase/C: unchanged) on the fourth property of a gas under the conditions given for the other three properties. For example, in case 1 write "A" or "B" or "C" to indicate what happens to the volume of a fixed amount of gas when its pressure is kept constant while its temperature is decreased. In the sixth column, identify the relevant gas law for cases 1, 3, 4 and 5 by writing the Roman numeral which corresponds to the law:

(I: Avagadro's Law; II: Boyle's Law; III: Charles' Law;
IV: Dalton's Law; V: Gay-Lussac's Law; VI: Ideal Gas Law.)

CASE	AMOUNT	PRESSURE	TEMPERATURE	VOLUME	GAS LAW
1	unchanged	unchanged	decreased		
2	increased		unchanged	unchanged	[redacted]
3	unchanged	decreased		unchanged	
4	unchanged		unchanged	increased	
5		unchanged	unchanged	increased	

2. A gas, G, initially at a temperature of 27 ^{0}C and a pressure of 1.00 atmospheres is moved from a 25-mL gas jar to a 75-mL gas jar where its pressure becomes 380 torrs. Circle the letter which corresponds to the most appropriate response in each case below.

(i) The temperature of gas G in the 75-mL flask is now, in ^{0}C,
A -73 B 40.5 C 177 D 200 E 450 F 723 G 1800
H 342000

(ii) At 27 ^{0}C the number of moles of gas G in the sample is
A 8.33 x 10^{-5} B 0.00102 C 0.011 D 0.615 E 0.772 F 1.02
G 8.58 H 89 I 985 F Correct answer not shown
The gas law involved is ________. (Use the gas law list from question 1)

(iii) When the sample of gas G is warmed to 37 ^{0}C the number of moles of gas in the sample is
A decreased B increased C unchanged
D Insufficient information provided

(iv) At S.T.P. 1.60 g of gas G (40.0 g/mol) has a volume of
A 1.78 mL B 350 mL C 897 mL D 1.12 L E 2.86 L F 560 L
G 1434 L H Correct answer not shown

(v) If neon gas at a partial pressure of 200 torrs and krypton gas at a partial pressure of 17 torrs are at 4.00 K in a 100-mL gas jar, adding 0.3 moles of gas G would make the pressure in the gas jar (in torrs)
A 0.009846 B 0.9846 C 7.48 D 210 E 216 F 217
G 218 H 224 I 543 J 748 K 760 L 965
M Correct answer not shown
The gas laws involved are ________ and ________. (Use the gas law list from question 1)

APPENDIX V

MIDAS Instruction Sheet for CH301 Student Subjects

1. For *NAME:* First four (4) letters of your last name followed by your first initial. For example, if your name is Pat Ramsey your identity is **RAMSP.**

2. For *BIRTH DATE* put the **date you do the MIDAS.**

3. For *IDENTIFICATION NUMBER:* <u>4 digits</u>: **birth month followed by birth date.**
   For example, if you were born May 26 your identification number is 0526
   if you were born April 9 your identification number is 0409
   if you were born November 23 your identification number is1123
   if you were born October 7 your identification number is 1007

4. For *SPECIAL CODE:* indicate your CH 301 class as follows in column K:
   0 Brodbelt
   1 Davis
   2 Fakhreddine
   3 Lyon (8 a.m.)
   4 Lyon (3 p.m.)
   5 Sparks
   6 Vanden Bout
   7 Jones
   8 LaBrake

5. **Please remember to return the scantron along with the MIDAS as soon as you have completed it.**

THANK YOU VERY MUCH FOR YOUR PARTICIPATION.

YOU WILL BE GIVEN THE RESULTS AS SOON AS YOUR MULTIPLE INTELLIGENCES ARE PROFILED.

APPENDIX W

Evaluation Questionnaire for Session 1

INDICATE TUTORIAL CODE:

RATE THE TUTORIAL THAT YOU COMPLETED TO INDICATE THE EXTENT OF YOUR AGREEMENT WITH THE STATEMENTS.

		high				**low**
1.	Appropriate length of time (not too long)	5	4	3	2	1
2.	Appropriate length of time (not too short)	5	4	3	2	1
3..	Narrator's voice clear	5	4	3	2	1
4.	Narration easy to follow and understand	5	4	3	2	1
5..	Information adequate for topic (not too much)	5	4	3	2	1
6..	Information adequate for topic (not too little)	5	4	3	2	1
7.	Explanations easy to follow	5	4	3	2	1
8.	Visuals clear, easily to read/see	5	4	3	2	1
9.	Adequate number of examples (not too many)	5	4	3	2	1
10.	Adequate number of examples (not too few)	5	4	3	2	1
11.	Useful examples	5	4	3	2	1

THANK YOU FOR YOUR PARTICIPATION.
SEE YOU AGAIN NEAR THE MIDDLE OF THE SEMESTER

APPENDIX X

Evaluation Questionnaire for Session 2

INDICATE TUTORIAL CODE: CB –

RATE THE TUTORIAL THAT YOU COMPLETED TO INDICATE THE EXTENT OF YOUR AGREEMENT WITH THE STATEMENTS.

		high				**low**
1.	Appropriate length of time (not too long)	5	4	3	2	1
2.	Appropriate length of time (not too short)	5	4	3	2	1
3..	Narrator's voice clear	5	4	3	2	1
4.	Narration easy to follow and understand	5	4	3	2	1
5..	Information adequate for topic (not too much)	5	4	3	2	1
6..	Information adequate for topic (not too little)	5	4	3	2	1
7.	Explanations easy to follow	5	4	3	2	1
8.	Visuals clear, easily to read/see	5	4	3	2	1
9.	Adequate number of examples (not too many)	5	4	3	2	1
10.	Adequate number of examples (not too few)	5	4	3	2	1
11.	Useful examples	5	4	3	2	1

THANK YOU FOR YOUR PARTICIPATION.
SEE YOU AGAIN TOWARD THE END OF THE SEMESTER

APPENDIX Y

Evaluation Questionnaire for Session 3

INDICATE TUTORIAL CODE: GL –

RATE THE TUTORIAL THAT YOU COMPLETED TO INDICATE THE EXTENT OF YOUR AGREEMENT WITH THE STATEMENTS.

		high				low
1.	Appropriate length of time (not too long)	5	4	3	2	1
2.	Appropriate length of time (not too short)	5	4	3	2	1
3..	Narrator's voice clear	5	4	3	2	1
4.	Narration easy to follow and understand	5	4	3	2	1
5..	Information adequate for topic (not too much)	5	4	3	2	1
6..	Information adequate for topic (not too little)	5	4	3	2	1
7.	Explanations easy to follow	5	4	3	2	1
8.	Visuals clear, easily to read/see	5	4	3	2	1
9.	Adequate number of examples (not too many)	5	4	3	2	1
10.	Adequate number of examples (not too few)	5	4	3	2	1
11.	Useful examples	5	4	3	2	1

THANK YOU FOR YOUR PARTICIPATION.

PLEASE FILL OUT THE *MIDAS* AND RETURN IT AS SOON AS POSSIBLE. YOU WILL BE GIVEN YOUR MULTIPLE INTELLIGENCE PROFILE AS SOON AS POSSIBLE AFTER I RECEIVE THEM

REFERENCES

1. Lagowski, J. J. "Lessons for the 21st Century: 1999 James Flack Norris Award, sponsored by ACS Northeast Section," *J. Chem. Educ.,* **2000,** *77,* 818-823.

2. Moore, John W. "The Chemistry-Biology Connection," *J. Chem. Educ.,* **2002,** *79,* 1287.

3. Hawkes, Stephen J. "What Chemistry to Teach Engineers?" *J. Chem. Educ.,* **2000**, *77,* 321-326**.**

4. Boggs, James E. "Science and Contemporary Social Problems," *J. Chem. Educ.,* **1972,** *49,* 189-191.

5. Herron, J. Dudley "Piaget for Chemists: Explaining What "Good" Students Cannot Understand," *J. Chem. Educ.,* **1975,** *52,* 146-150.

6. Wagner, Eugene P.; Sasser, Howell; DiBiase, Warren J. "Predicting Students at Risk in General Chemistry Using Pre-semester Assessments and Demographic Information," *J. Chem. Educ.,* **2002,** *79,* 749-755.

7. Atwater, Mary Monroe, "Equity for Black Americans in Pre-college Science," *Science Education,* **2000,** *84,* 154-179.

8. Mulford, Douglas R.; Robinson, William R. "An Inventory for Alternate Conceptions among First-Semester General Chemistry Students," *J. Chem. Educ.,* **2002,** *79,* 739-744.

9. Meehan, Dawna-Cricket-Martita; Negy, Charles. "Undergraduate Students' Adaptation to College: Does Being Married Make a Difference?" *J. Coll. Stud. Dev.,* **2003,** *44,* 670-690.

10. Pascarella, Ernest T.; Pierson, Christopher T.; Wolniak, Gregory C.; Terenzini, Patrick. "First-Generation College Students: Additional Evidence on College Experience and Outcome," T*. J. Higher Educ. (Columbus),* **2004,** *75,* 249-284.

11. Tobias, Sheila *They're Not Dumb, They're Different: Stalking the Second Tier.* Tucson, AZ, **1990.**

12. Mbamalu, Godwin E. "Teaching Science to Academically Underprepared Students," *J. Sc. Educ. and Tech.,* **2001,** *10,* 267-272.

13. Gabel, Dorothy "Improving Teaching and Learning through Chemistry Education Research: A Look to the Future," *J. Chem. Educ.,* **1999,** *76,* 548-554.

14. Spencer, Harry E. “Mathematical SAT Test Scores and College Chemistry Grades,” *J Chem Educ.,* **1996,** *73,* 1150-1153.

15. Ficher, Gwen Laura “The Validity of Pre-Calculus Multiple Choice and Performance-Based Testing as a Predictor of Undergraduate Mathematics and Chemistry Achievement.” Eric Document Reproduction Service ED409369 Master’s Thesis, University of California, Santa Barbara, Dec **1969**.

16. Gardner, Howard, *Frames of Mind: The Theory of Multiple Intelligences*. Basic Books, Inc. N.Y., **1983**.

17. Cornog, Jacob; Stoddard, George D. “Predicting Performance in Chemistry,” *J. Chem. Educ.,* **1925,** *2,* 701-708.

18. Mason, Diana “Transitions and Interfaces,” *J. Chem. Educ.,* **2002,** *79,* 1289.

19. Powers, S. R. “Tests of Achievement in Chemistry,” *J. Chem. Educ.,* **1924,** *1,* 139-144.

20. Rich, S. G. “*Rich’s Chemistry Tests Manual,”* Public School Publishing Co., **1923**.

21. Powers, S. R. “*Power’s General Chemistry Test,”* World Book Co., **1924**.

22. Stout, Lawrence E. “The Selective Value of Powers’ General Chemical Test, Scale “A”,” *J. Chem. Educ.,* **1926,** *3,* 1138-1143.

23. Wolf, Milton G. “The Relation between the Degree of Intelligence and Success in the Study of Chemistry,” *J. Chem. Educ.,* **1928,** *5,* 76-83.

24. Ozsogomonyan, A.; Loftus D. “Predictor of General Chemistry Grade,” *J Chem Educ.,* **1979,** *56,* 173-175.

25. Bunce, Diane M.; Hutchinson, Kira D. “The Use of GALT (General Assessment of Logical Thinking) as a Predictor of Academic Success in College Chemistry,” *J. Chem. Educ.,* **1993,** *70,* 183-187.

26. Legg, Margaret J.; Legg, Jason C.; Greenbowe, Thomas J. “Analysis of Success in General Chemistry Based on Diagnostic Testing Using Logistic Regression,” *J. Chem. Educ.,* **2001,** *78,* 1117-1121.

27. http://www3.uwm.edu/dept/chemexams/about/index.cfm

28. http://www.uwm.edu/Dept/chemexams/.

29. Pienta, Norbert J. “A Placement Examination and Mathematics Tutorial for General Chemistry,” *J. Chem. Educ.,* **2003,** *80,* 1244-1246.

30. Stokstad, Erik “Reintroducing the Intro Course,” *Science,* **2001,** *293*, 1608-1610.

31. Guild, Pat Burke; Chock-Eng, Sandy “Multiple Intelligences, Learning Styles, Brain-Based Education: Where Do the Messages Overlap?” *Schools in the Middle,* **1998,** 7, 38-40.

32. Wooldridge, Blue “Increasing Effectiveness of University/College Instruction: Integrating the Results of Learning Style Research into Course Design and Delivery,” in Sims, Ronald R. and Sims, Serbrenia J., eds., *The Importance of Learning Styles: Understanding the Implications for Learning, Course Design, and Education.* Greenwood Press, Westport, CT, **1995,** 49-67.

33. Sims, Ronald R.; Sims, Serbrenia J., “Learning Enhancement in Higher Education” in *The Importance of Learning Styles: Understanding the Implications for Learning, Course Design, and Education,* Sims, Ronald R. and Sims, Serbrenia J., eds., Greenwood Press, Westport, CT, **1995,** 1-24.

34. Stefanakis, Evangeline Harris *Multiple Intelligences and Portfolios,* Heinemann, Portsmouth, NH **2002.**

35. Gardner, Howard *Intelligence Reframed: Multiple Intellligences for the Twenty-first Century*. Basic Books, NY, **1999**.

36. Barke, Hans-Dieter; Engida, Temechegn “Structural Chemistry and Spatial Ability in Different Cultures,” *Chem. Educ. Res. Pract.* **2001**, *2*, 227-239.

37. Williamson, Vickie; Huffman, Jason; Peck, Larry “Testing Students’ Use of the Particulate Theory,” *J Chem Educ.,* **2004,** *81,* 891-896.

38. Mathewson, James H. “Visual-spatial Thinking: An Aspect of Science Overlooked by Educators,” *Science Education*, **1999,** *83*, 33-54.

39. Coleman, Sharon L.; Gotch, Albert J. “Spatial Perception Skills of Chemistry Students,” *J Chem Educ.,* **1998,** *75,* 206-209.

40. Zare, Richard N. “Visualizing Chemistry,” *J Chem Educ.,* **2002,** *79,* 1290-1291.

41. Taagepera, Mare; Arasasingham, Ramesh; Potter, Frank; Soroudi, Arash; Lam, Giang “Following Development of the bonding Concept Using Knowledge Space Theory,” *J Chem Educ.,* **2002,** *79,* 756-762.

42. Gabel, Dorothy J.; Bunce, Diane M. “Improving Chemistry Achievement through Emphasis on the Particulate Nature of Matter,” *Proceedings of the 64th Annual NARST Conference,* Lake Geneva, WI, **1991**.

43. Williamson, Vickie M.; Abraham, Michael R. "The Effects of Computer Animation on the Particulate Mental Models of College Chemistry Students," *J Res. Sc. Teach.,* **1995,** *32,* 521-534.

44. Miller, Gordon J.; Verkade, John G. "A Pictorial Approach to Molecular Orbital Bonding in Polymers: Non-Mathematical but Honest," *J Chem Educ.,* **1999,** *76*, 428-433.

45. Lang, Patricia; Towns Marcy Hamby "Visualization of Wave Functions Using Mathematica," *J Chem Educ.,* **1998,** *75*, 506-509.

46. Gabel, Dorothy J.; Samuel, K. V.; Hunn Diana "Understanding the Particulate Nature of Matter," *J Chem Educ.,* **1987,** *64*, 695-697.

47. Sanger, Michael J. "Using Particulate Drawings to Determine and Improave Students' Conceptions of Pure Substances and Mixture," *J Chem Educ.,* **2000,** *77*, 762-766.

48. Niaz, Mansoor; Robinson, William R. "From 'Algorithmic Mode' to 'Conceptual Gestalt in Understanding the Behavior of Gases: An Epistemological Perspective," *Research in Science and Technological Education,* **1992,** *10*, 53-54.

49. Felder, Richard M. "Active-Inductive-Cooperative Learning: An Instructional Model for Chemistry?" *J Chem Educ.,* **1996,** *73,* 832-836.

50. Lerman, Zafra, M. "Using the Arts To Make Chemistry Accessible to Everyone," *J Chem Educ.,* **2003,** *80,* 1234-1243.

51. Francisco, Joseph S.; Nicoll, Gayle; Trautmann, Marcella "Integrating Multiple Teaching Methods into a General Chemistry Classroom" *J Chem Educ.,* **1998,** *75,* 210-213.

52. Brown Wright Gloria A. "Teaching Chemistry in Three-Hour Blocks" Paper presented at the 15^{th} Biennial Conference on Chemical Education, University of Waterloo, August **1998**.

53. Jones Tricia; Berger, Carl "Students' Use of Multimedia Science Instruction: Designing for the MTV Generation," *J. Educational Multimedia and Hypermedia* **1995** 4 305-320.

54. Pickrell, John "Open University: A Pioneer Presses," *Science,* **2001,** *293*, 1621-1622

55. Castelberry, Sam J.; Culp, George H.; Lagowski, J. J. "The Impact of Computers On Undergraduate Chemical Education" ERIC_NO: ED116615, **1973**.

56. Nakhleh, Mary B.; Krajcik, Joseph S. "The Effect of Level of Information as Presented by Different Technologies on Students' Understanding of Acid, Base, and pH Concepts," *Proceedings of the 64th Annual NARST Conference,* Lake Geneva, WI, **1991**.

57. Montgomery, Susan M. "Multimedia for Chemical Engineering: Module Development and Lessons Learned," *Computer Applications in Engineering Educ.,* **1996,** *4,* 297-305.

58. Springer, Sally P.; Deutsch, Georg *Left Brain, Right Brain.* W. H. Freeman & Company, San Francisco, **1981**.

59. Sperry, Roger W. "Forebrain Commissurotomy and Conscious Awareness" in *Brain Circuits and Functions of the Mind: Essays in Honor of Roger W. Sperry,* Colwyn Trevarthen, ed., Cambridge University Press, Cambridge, **1990**, 371-388.

60. Hunter, Walter E.; McCants, Louise S. "The New Generation Gap: Involvement Vs. Instant Information" Topical Paper No. 64, ERIC_NO:ED148412, **1977**.

61. Purkiss, William "Learning Styles and the Changing Face of Community Colleges," in Sims and Sims, **1995**.

62. McCarthy, Bernice *The 4MAT System: Teaching to Learning Styles with Right/Left Mode Techniques.* Excel Inc, IL, **1981**.

63. Benowitz, Larry, L; Finkelstein, Seth; Levin, David; Moya, Kenneth "The Role of the Right Cerebral Hemisphere in Evaluating Configurations" in *Brain Circuits and Functions of the Mind: Essays in Honor of Roger W. Sperry,* Colwyn Trevarthen, ed., Cambridge University Press, Cambridge, **1990**, 320-333.

64. Kolb, David. A. *Experience as the Source of Learning and Development.* Prentice-Hall, Englewood Cliffs, NJ, **1984**.

65. Rainey, Mary Ann; Kolb, David A. "Using Experiential Theory and Learning Styles in Diversity Education" in *The Importance of Learning Styles: Understanding the Implications for Learning, Course Design, and Education,* Sims, Ronald R. and Sims, Serbrenia J., eds., Greenwood Press, Westport, CT, **1995,** 129-146.

66. Boyatzis, Richard E.; Cowen, Scott S.; Kolb, David. A. and associates "What if Learning Were the Purpose of Education?" in *Innovation in Professional Education: Steps on a Journey from Teaching to Learning.* Jossey-Bass Publishers, San Francisco, **1995**.

67. Wink, Donald J. "Reconstructing Student Meaning: A Theory of Perspective Transformation," Online Symposium: Piaget, Constructivism and Beyond," *J. Chem. Educ.,* **2001,** *78*, 1107.

68. Mezirow, Jack *Transformative Dimensions of Adult Learning*. Jossey Bass: San Francisco, **1991**.

69. Mezirow, Jack "How Critical Reflection Triggers Transformative Learning," in *Fostering Critical Reflection in Adulthood: A Guide to Transformative and Emancipatory Learning.* Jossey Bass: San Francisco, **1990**, 1-20.

70. Hickcox, Leslie K. "Learning Styles: A Survey of Adult Learning Style Inventory Models," in *The Importance of Learning Styles: Understanding the Implications for Learning, Course Design, and Education,* Sims, Ronald R. and Sims, Serbrenia J., eds., Greenwood Press, Westport, CT, **1995**, 25-47.

71. Dunn, Rita; Dunn, Kenneth, *Teaching Students Through Their Individual Learning Styles: A Practical Approach.* Reston Publishing Company Inc., Reston, VA, **1978.**

72. Dunn, Rita; Dunn, Kenneth; Price, Gary E. "Identifying Individual Learning Styles" in *Student Learning Style: Diagnosing and Prescribing Programs*, National Association of Secondary School Principals, Reston, VA, **1979**, 39-54.

73. Dunn, Rita; Griggs, Shirley A. *Multiculturalism and Learning Style: Teaching and Counseling Adolescents.* Praeger, Westport, CT **1995**.

74. Dunn, Rita; Griggs, Shirley A. *Learning Style: Quiet Revolution in America's Schools.* National Association of Secondary Principals, Reston, VA, **1998.**

75. Dunn, Rita, Griggs, Shirley A., eds., *Practical Approaches to Using Learning Styles in HigherEducation.* Bergen and Garvey, Westport, CT, **2000.**

76. Geary William T.; Sims, Ronald R.; "Adapting Faculty and Student Learning Styles: Implications for Accounting Education," in *The Importance of Learning Styles: Understanding the Implications for Learning, Course Design, and Education,* Sims, Ronald R. and Sims, Serbrenia J., eds., Greenwood Press, Westport, CT, **1995**, 117-127**.**

77. Harrison, Allan G.; Treagust, David F. "Conceptual Change Using Multiple Interpretive Perspectives: Two Cases Studies in Secondary School Chemistry," *Instructional Science,* **2001,** *29,* 45-85.

78. McCleary, L. E.; McIntyre, K. E. "Competency Development and University Methodology," *The National Association of Secondary School Principals Bulletin*, **1972**.

79. Carroll A. J.; Paine, F. T.; Ivancevich J. ”The Relative Effectiveness of Training Methods – Expert Opinion and Research,” J. *Personnel Psychology,* **Autumn 1972,** *25,* 495-509.

80. Campbell, Linda; Campbell, Bruce *Multiple Intelligence and Student Achievement: Success Stories from Six Schools*, 3rd ed., Allyn and Bacon, Boston, MA **2004**.

81. Gardner, Howard *The Mind's New Science: A History of the Cognitive Revolution*. Basic Books, NY, **1999**.

82. Linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal, intrapersonal.

83. The criteria are: potential isolation by brain damage; the existence of idiots savants, prodigies and other exceptional individuals; an identifiable core of operation or set of operations; a distinctive developmental history, along with a definable set of expert “end-state” performances; an evolutionary history and evolutionary plausibility; support from experimental psychological tasks; support from psychometric findings; susceptibility to encoding in a symbol system.

84. Naturalistic, spiritual

85. Gardner, Howard *Multiple Intelligences: The Theory in Practice*. Basic Books, New York, **1993**.

86. Gardner, Howard *The Disciplined Mind: What All Students Should Understand.* Simon and Schuster, New York, **1999**.

87. Gardner, Howard *The Well-Disciplined Mind: Beyond Facts and Standardized Test, the K-12 Education that Every Child Deserves.* Penguin USA, **2000**.

88. Kornhaber, Mindy L.; Fierro, Edward Garcia; Veenema, Shirley A. *Multiple Intelligences: Best Ideas From Research and Practice.* Pearson Education, Inc., Boston, MA, **2004**.

89. Gardner, Howard *The Unschooled Mind: How Children Think and How Schools Should Teach*. Basic Books, NY, **1991**.

90. Guild, Pat Burke; Garger, Stephen *Marching to Different Drummers,* 2nd ed., Association for Supervision and Curriculum Development, Alexandria, VA, **1998**.

91. Campbell, Linda; Campbell, Bruce; Dickinson, Dee *Teaching and Learning Through Multiple Intelligences,* 3rd ed., Allyn and Bacon, Boston, **2004.**

92. Diaz-Lefebvre, Rene; Sieter, Nancy; Pollack, Tessa Martinez "What If They Learn Differently: Applying Multiple Intelligences Theory in The Community College," *Leadership Abstracts*, **1998**, *11*, www edition.

93. Diaz-Lefebvre, Rene "Multiple Intelligences, Learning for Understanding, and Creative Assessment: Some Pieces to the Puzzle of Learning," *Teachers College Record*, **2004**, *106*, 49-57.

94. Malm, Nelda Weaver "Distribution of Gardner's Multiple Intelligences Among Students and Faculty in Associate Degree Career Programs," *Dissertation Abstracts International*, **2001**, *62-01*, Section A, 60.

95. Silver, Harvey F.; Strong, Richard W.; Perini, Matthew J. "So Each May Learn," Association for Supervision and Curriculum Development, Alexandria, VA, **2000**.

96. Dare, Donna E. "Learning-Centered Instructional Practices Supporting the New Vocationalism," *New Directions for Community Colleges*, **2002**, *2001(115)*, 81-91.

97. Habraken, Clarisse L. "Integrating into Chemistry Teaching Today's Student's Visuospatial Talents and Skills, and the Teaching of Today's Chemistry's Graphical Language," *J. Sc. Educ. Tech.*, **2004**, *13*, 89-94.

98. Boo, H.K. "Applications of Multiple Intelligences Theory to Chemistry Teaching and Learning," Chemistry Education International, **2002,** *3,* No. 1, AN-6.

99. Sweet, Sharon "A Lesson Learned about Multiple Intelligences," *Educational Leadership,* **1998,** *56*, 50-51.

100. Kirby, John R. "Collborative and Competitive Effects of Verbal and Spatial Processes," *Learning and Instruction*, **1993**, *3*, 201-214.

101. Schnotz, Wolfgang; Bannert, Maria "Construction and Interference in Learning from Multiple Representation," **2003**, *13*, 141-156.

102. Brown Wright, Gloria A. "The Relationship Between a Graduate Student's Multiple Intelligences and Chemistry Division," Poster presented at National ACS Meeting, April, **2002**.

103. May be ordered at www.MIResearch.org

104. Rickey, Dawn; Stacy, Angelica M. "The Role of Metacognition in Learning Chemistry," *J. Chem. Educ.,* **2000,** *77,* 915-920.

Vita

Gloria Aileen Brown Wright was born in New Market, St. Elizabeth, Jamaica to Ivan Wesley Brown and Beryl Gwendolyn Blagrove Brown on January 8, 1947. She attended the Montego Bay High School where she successfully sat the Cambridge University Senior Certificate examinations in 1963 and the Cambridge University Advanced Level Examinations in 1965. She then entered Andrews University, Berrien Springs, Michigan, U. S. A. and in 1970 earned a Bachelor of Arts degree in Chemistry (concentration) and French. She spent the 1968-69 school year studying in France, and obtained Alliance Française diplomas in French language and literature. She spent 1971 as a volunteer teacher in Indonesia, and in September 1972 enrolled as a graduate student in the chemistry department of the Ohio State University, obtaining a Master of Science degree in physical chemistry in 1975, after which she joined her husband in the Bahamas where their daughter, Karla, was born. In 1981 she completed a post-graduate diploma in education from the University of the West Indies, Mona, Jamaica. After years of college chemistry teaching and administration she returned to the life of a student, joining the Department of Chemistry and Biochemistry at the University of Texas, Austin, in 1999 to pursue doctoral studies in chemistry education research.

Permanent address: 73 Cedar Avenue
Apartment 71
Long Branch, NJ 07740

This dissertation was typed by the author.