The Effect of Thinking Preferences on Laboratory Group Achievement of Inquiry Skills in Introductory Biology

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Approval Page

This applied dissertation was submitted by Harley Dale Epperson under the direction of the persons listed below. It was submitted to the Fischler School of Education and Human Services and approved in partial fulfillment of the requirements for the degree of Doctor of Education at Nova Southeastern University.

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Abstract

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This applied dissertation was undertaken to investigate whether a difference in attainment of biology inquiry skills resulted from students' participation in a laboratory program that was based on learning style preferences. Students were placed in groups according to their individual thinking preferences. Based on the results of G. Browning's (2006) Emergenetic® profile, students were placed in 2 different types of groups. Whole Emergenetic® groups were formed of students with preferences for four thinking styles: (a) structural, (b) analytical, (c) conceptual, and (d) social. Like Emergenetic® groups were formed of students with similar thinking style preferences. A 35-item test of biology inquiry skills was administered before and after the intervention to measure increases in students' inquiry skills.

An attempt was made to provide sufficient data to answer 3 research questions:

1. How does inclusion in a Whole Emergenetic® laboratory group affect students' attainment of inquiry skills as indicated by their scores on the pre- and posttest?
2. How does inclusion in a Like Emergenetic® laboratory group affect students' attainment of inquiry skills as indicated by their scores on the pre- and posttest?
3. Within Like Emergenetic® groups, is there a significant difference in students' attainment of inquiry skills in the four different types of groups?

Results indicated that the type of group that a student was assigned to did have an effect on the student's attainment of inquiry skills. Members of the Whole Emergenetic® teams demonstrated a statistically significant increase in scores from the pretest to the posttest. Members of the Like Emergenetic® teams also increased their scores on the assessment instrument, but the increases were not statistically significant and could have been the result of chance occurrence.

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Chapter 1: Introduction

Maximizing the learning of each student in every classroom should be the goal of the professional educator. This is not to say, however, that all students can achieve at the same rate or at the same level of achievement. The emphasis must be on tapping the potential of every student. In a perfect educational setting, each student would reach his or her own intellectual potential, and all teachers would employ techniques that would enhance the learning process for each individual student. It would be hard to imagine that anyone could find fault with these statements as a general goal for education. Increased student achievement is a goal that has been recognized by both the legislative and executive branches of the federal government. According to the U.S. Department of Education (n.d.),

> On January 8, 2002, the No Child Left Behind Act became the education law of the land providing parents and children with the resources they need to ensure academic success. There is an educational achievement gap in this country, and No Child Left Behind is helping to close it. (Statement of U.S. Secretary of Education Rod Paige on Black History Month section, ¶ 5)

Having every student achieve high standards persists as a valuable goal. The question that remains is how to achieve this goal.

Although the above-mentioned goals are admirable and worthy, experience teaches that maximizing student achievement in each student occurs rarely, if at all. Numerous factors inherent in the teaching profession impede the process of achieving theoretical goals. The real question is not whether maximizing learning should be a goal, but whether educators have at their disposal the methods, techniques, and information necessary to increase student achievement in terms of their learning to a significant degree. Almost on a daily basis, educators are bombarded with innovative ideas or processes touted as a “better mousetrap” in terms of student achievement.

In addition to the mandates from the federal government regarding student achievement, educators face other concerns, such as the effects of ethnicity on students' educational attainment. Trusty and House (2004) wrote, "In 2001, for example, the percentages of those with a bachelor's degree or higher were 33 percent for non-Latino whites, 18 percent for blacks, and 11 percent for Latinos" (p. 12). Obviously, the playing field is not level for all ethnic groups. Given this reality, it is imperative to identify the factors that have the greatest influence on these differences. Trusty and House identified a student's participation in intensive science and mathematics courses while in high school as the best indicator of success at the college level. According to Trusty and House, "The effects of getting credit in one of these courses [intense mathematics or science] is stronger than the effects of high school grades, class rank, or GPA [grade point average]; scores on academic achievement tests; or credit in other courses" (p. 12). Intensive mathematics and science courses engender greater success regardless of the students' race, gender, or income level. These powerful observations cannot be ignored.

Another area of interest is the impact of laboratory activities. The National Science Teachers Association (n.d.) recommended that at the high school level, "All high school science courses must offer laboratory experiences for all students . . . . [and] a minimum of 40 percent of the science instruction time should be spent on laboratory related activities" (p. 2). This recommendation was echoed by the Georgia Department of Education (n.d.). The recommendation by these two organizations that each science class should include a significant amount of laboratory time indicates the importance of the laboratory experience and must not be ignored.

This research study was an attempt to explore how student achievement could be improved in an intensive laboratory setting. The study took place at a private college preparatory school for students of average to superior ability. The school, which is governed by a board of trustees, is located in West Central Georgia. The 822 prekindergarten to Grade 12 students who were enrolled at the school were primarily from upper-middle-class families who lived in an urban setting. The student-to-teacher ratio at the time of the study was 11:1. The faculty was 30% male and 70% female, 70% of the faculty members held advanced degrees, and they had an average of 20.6 years of experience.

The student population was composed of 404 males and 418 females. The racial breakdown of the student population was as follows: 90.50% Caucasian, 3.03% African American, 0.60% Hispanic, 3.28% Asian American, 1.21% Middle Eastern American, and 1.34% multiracial. Over the past 10 years, the average grade point average (GPA) of graduates was 3.29, the average Scholastic Aptitude Test score was 1,205, and 70.5% of students scored 3 or higher on advanced placement exams. The study included 93 students who were enrolled in 9th- and 10th-grade introductory biology classes.

At the time of this study, the researcher had been a teacher at the school for 24 years. Additionally, the researcher had served as the head of the Science Department for the past 15 years and had served as the assistant principal in charge of discipline for the past 9 years. As the department head and assistant principal, the researcher was a member of the school-wide Curriculum Committee. Membership on the Curriculum Committee allowed the researcher to have influence on curriculum decisions at all levels.

In the area of science instruction, grouping students together in teams to conduct laboratory exercises is a common practice. The practical reasons for using teams in the laboratory are twofold. First, the use of teams cuts down on the amount of materials needed, which reduces costs. Second, the use of teams reduces the need for space; in most schools, the space for laboratory exercises is limited.

Teachers generally group students for laboratory exercises by using one of three methods. Some teachers group students randomly, but this method serves no purpose other than convenience to the teacher. Other teachers allow students to self-select their laboratory groups. Again, this process is convenient for the teacher, but allowing students to self-select can be detrimental to students who are left out or not chosen for a particular group. Therefore, this process can have an adverse effect on student learning during laboratory exercises. Another method for forming laboratory teams involves placing students in certain groups to avoid discipline problems from occurring. Although each of these methods seems valid on the surface, none of them has been shown to enhance student learning during laboratory exercises.

Statement of the Problem

As outlined above, educators are under pressure to (a) increase student achievement, (b) improve students' critical-thinking skills, and (c) enhance achievement at the college level by ensuring that each student is exposed to an intensive science curriculum. Schools must adhere to recommended guidelines regarding the amount of time that students spend in laboratory activities. Traditional grouping techniques for laboratory exercises have not always been educationally sound. By investigating the possibility of increasing student achievement in an intensive science laboratory setting, the researcher hoped to address all of these problems at one time.

This private school does not use standardized state-developed tests in order to assess students. In kindergarten to Grade 8, the Stanford Achievement Test, ninth edition, is used. In Grades 9-12, the Preliminary Scholastic Aptitude Test is used. An analysis of Stanford Achievement Test scores for eighth-grade students for the past 4 years revealed an average score of 69.33 on the science component of the test as reported by the mean normal curve equivalent (NCE). The mean NCE is defined as a direct conversion from percentile ranks resulting from the division of the normal curve into 99 equal units. An NCE score of 50 represents the national mean score for a particular subtest. The school's mean science score of 69.38 was 19.38 points above the national average. In addition, students at the school scored 72.98 in mathematics, 67.78 in reading, 70.88 in language, and 68.15 in social studies. Although these scores were not necessarily poor, there was room for improvement.

Additional support for an intervention that was designed to improve students' achievement in science was found in two other areas. First, in a variety of parent surveys that had been administered over the past few years, parents were asked to indicate the curriculum areas they felt were in need of improvement. On these surveys, 19% of the respondents indicated that the school's science curriculum was in need of change. According to the parents who were surveyed, science was second only to mathematics in importance. Second, discussion at curriculum meetings of the Science Department increasingly centered on how to improve science instruction, specifically the laboratory component. The prevailing perception among faculty members in the Science Department was that students were not getting the maximum benefit from their laboratory experiences. These perceptions were based on personal observations made by the faculty members.

Given the students' Stanford Achievement Test scores, the parents' perceptions of the need for improvements in the science curriculum, and the faculty members' perceptions of the need to improve the laboratory component of the science curriculum, the researcher believed that grouping techniques were worthy of investigation. The purpose of this applied dissertation was to investigate the effect of laboratory team formation that was based on Browning's (2006) Emergenetics® thinking preferences profile on students' attainment of inquiry skills in an introductory biology class laboratory program.

Purpose of the Research Study

The purpose of this study was to investigate the effects of grouping--Whole Emergenetics® teams (WETeams ™) versus Like Emergenetics (LETeams ™)--based on Emergenetics® thinking preferences, as described by Browning (2006), on the completion of a series of biology laboratory exercises and to determine what effects, if any, the groupings have on the level of attainment of inquiry skills obtained by each student. Students' scores on pre- and posttests were compared to measure the effects of the intervention.

Research Questions

The study was designed to answer the following research questions:

1. How does inclusion in a WETeam™ laboratory group affect students' attainment of inquiry skills?

2. How does inclusion in a LETeam™ laboratory group affect students' attainment of inquiry skills?

3. Within LETeams™, is there a significant difference in students' attainment of inquiry skills in the four different types of groups?

Definitions of Terms

Abstract-thinking preference. This term refers to a thinking style that is characterized by a preference for both conceptual and analytical thinking (Browning, 2006).

Analytical-thinking preference. This term refers to a thinking style that is characterized by enjoying technical problems, displaying logic, having a propensity for mathematics and science, easily grasping concepts and ideas, and exploring how things work (Browning, 2006).

Conceptual-thinking preference. This term refers to a thinking style that is characterized by enjoying creative processes, being imaginative, solving problems intuitively, and having the need to try new things (Browning, 2006).

Concrete-thinking preference. This term refers to a thinking style that is characterized by a preference for both structural and social thinking (Browning, 2006).

Emergenetics®. This registered trademark refers to a blend of genetics and learned experiences expressed as a behavior and a way of thinking (Browning, 2006).

Inquiry skills. This term refers to the process of science in which students learn the skills of observation, inference, and experimentation (Germann, 1991).

Left-brain thinking. This term refers to a thinking style that is characterized by a preference for both structural and analytical thinking (Browning, 2006).

LETeam™. According to Browning (2006), this term refers to a laboratory group of 3-4 students all with the same preference for left-brain, right-brain, abstract, or concrete thinking.

Right-brain thinking. This term refers to a thinking style that is characterized by a preference for both conceptual and social thinking (Browning, 2006).

Social-thinking preference. This term refers to a thinking style that is characterized by enjoyment found in helping others (Browning, 2006).

Structural-thinking preference. This term refers to a preferred thinking style that is characterized by enjoying directions, being comfortable in predictable situations, employing a large degree of practicality, making and following directions, and needing closure (Browning, 2006).

WETeam™. According to Browning (2006), this term refers to a laboratory group of 3-4 students with a preference for four thinking styles: (a) structural, (b) analytical, (c) conceptual, and (d) social.

Chapter 2: Literature Review

Although increasing the achievement level of all students is an admirable and essential goal for educators, how to accomplish this goal remains a difficult question to answer. Over the past decade, a great deal of research has been conducted in an effort to unlock the secrets of the human brain. These studies have a direct connection to learning. Over the years, a plethora of educational research has outlined the benefits of cooperative education for students, and incorporation of inquiry skills into the science laboratory has been shown to be a useful tool for increasing students' problem-solving and higher order thinking skills.

Brain Research and Education

One of the more promising areas of interest to educators is the application of new information regarding the brain and how humans learn. A link has been established between what goes on in the classroom and the theories put forth by psychologists and neurologists. Brain research has confirmed what educators already knew--not all brains are the same (Hardiman, 2003). Genessee (2006) wrote,

> Educators must make provisions for individual differences in learning styles by providing alternative grouping arrangements, instructional materials, time frames, and so on. Individual differences in learning style may not be a simple matter of personal preference, but rather of individual differences in the hardwiring of the brain and, thus, beyond individual control. (p. 5)

In the insipient stages of neurologic and learning research, emphasis was placed on how the environment plays a crucial role. The so-called "nurturing effect" was the realm of researchers such as Pavlov and Skinner as they focused on how environmental conditioning shaped personality (Hardiman, 2003). The use of DNA and genetic profiles was in its infancy. The theory of how nature (i.e., the genetic makeup a person inherits from his or her parents) influences personality was not widely known, much less accepted. What was known about the brain in those days consisted of information obtained through autopsies and observing people whose brains had been damaged by injury or illness (Browning, 2006). With the advent of more sophisticated imaging techniques, it is now possible to "peer" into a thinking brain. All of this new brain information has produced progressively more complicated theories about learning.

According to Browning (2006), in the late 1970s, Sperry performed tests on split-brain patients, that is, individuals who had their corpus callosum severed to relieve the effects of severe epilepsy. From these studies emerged what we know about the two hemispheres of the brain, which are commonly referred to as left brain and right brain. These studies indicated that the left hemisphere of the brain processes information in a logical, rational, linear, sequential, analytic, and systematic manner. The right hemisphere, on the other hand, processes information in a more intuitive, emotional, holistic, and conceptual manner. Individuals generally rely more on one hemisphere or the other and rarely use one hemisphere or the other exclusively.

The fact that human beings have two distinct halves of their cerebrum, each responsible for certain functions, served as the impetus for the development of the 4MAT system developed by McCarthy (1990). The 4MAT system was designed to help teachers to organize their own teaching in order to make maximum use of differences in individual learners. McCarthy wrote, "4MAT is an eight-step cycle of instruction that capitalizes on individual learning styles and brain dominance processing preferences" (p. 31). The major advantage of the 4MAT system is that it takes into account that individuals have preferred learning styles and hemispheric ways of processing information. This model allows for designing and implementing classroom strategies so that each preference can be reached, and ultimately, learning can be improved. McCarthy's system also incorporates active learning as opposed to simple passive reflection by the student.

According to Browning (2006), the idea of the brain being divided into two halves progressed to the concept that the brain contains four quadrants that process abstract and concrete thinking in addition to logic and intuition. Concrete thinkers prefer facts, real-life examples, and action; abstract thinkers prefer ideas, concepts, and symbols. Browning noted that the combination of logic, intuition, and concrete and abstract thinking was introduced by Herrmann in the late 1970s. Herrmann referred to this combination as hemispheric lateralization. Browning pointed out that what Herrmann's research failed to take into account was the distinction between thinking and how humans behave. Browning and her colleagues developed a model that addresses how individuals prefer to think and what types of behaviors they tend to exhibit. The model is called Emergenetics®. Browning explained that the term refers to "patterns of thinking and behavior that emerge from one's genetic blueprint" (p. 39).

From her research, Browning (2006) determined that there are four distinct thinking attributes and three behavioral attributes. The thinking attributes are (a) analytical, (b) structural, (c) conceptual, and (d) social. The behavioral attributes are (a) expressiveness, (b) assertiveness, and (c) flexibility. Each person has a unique combination of the four thinking preferences and three behavioral preferences that produces a distinct Emergenetics® profile.

An important example of the use of Emergenetics® in the classroom is the formation of groups. By using individual Emergenetics® profiles, different types of groups can be formed to enhance student learning in particular classroom exercises. Two particular types of groups were of interest in this research, what Browning (2006) referred to as WETeams™ and LETeams™. Members of WETeams™ have preferences for all of the four thinking attributes: (a) structural, (b) analytical, (c) conceptual, and (d) social. In a LETeam™, all members have the same thinking style preference. The ability to place individuals in teams according to their individual Emergenetics® profiles is a direct result of Browning's work with various companies and organizations around the world that have utilized the profiles to form successful teams in the workplace.

There are numerous studies in the literature related to brain-based research and improving student achievement. Of particular note are those that employ the 4MAT system that was introduced by McCarthy (1990). Jackson (2001) investigated the effects of teaching methods and 4MAT learning styles on community college students' achievement, attitudes, and retention in an introductory microbiology course. In Jackson's study, two microbiology classes were taught with different techniques. One class was taught using the 4MAT learning styles model, and the other used a traditional lecture and discussion method. The results of this study indicated that students in the 4MAT group showed greater improvement in the areas of achievement, attitude, and retention than students in the traditional lecture and discussion group.

Lisoskie (1990) conducted further investigations into the use of brain-based research in the science classroom. Lisoskie pointed out that most high school science teachers use lecture, discussion, and objective testing, all of which are tailored to the left hemisphere of the brain. Because many students prefer to utilize their right hemisphere the majority of the time, this produces a situation in which the students are not in an environment suited to their individual learning styles. Lisoskie studied the use of the 4MAT system for teaching to both the right and left brain hemispheres. Here again, positive correlations were found regarding the relationship between the use of the 4MAT system and increased student achievement. Although these studies indicate that the use of brain-based teaching techniques can have an impact on student achievement, they did not address the impact of group formation in a science laboratory.

Another area of interest regarding brain research and cognitive functioning is seen in the research of Epstein (2003) who said that most theories of human cognitive abilities rely on psychosocial factors in order to describe what happens developmentally as human beings progress into mature adults. Epstein wrote, “Cognitive functions and changes are more readily and more accurately understood and described if attention is also, if not first, paid to the facts of brain growth” (p. 1). An understanding of how human brain growth relates to cognitive function will help educators find ways to enhance children’s cognitive development.

In his theory, Epstein (2003) outlined at least five stages of brain growth during the development of an individual from infancy to adolescence. During rapid periods of brain growth, the mass of the brain increases an average of 5-10%, and during slow growth periods, the increase is 1% at best (Epstein). This increase in brain mass includes significant expansion in three areas: (a) The number of synaptic connections increases, (b) axons of neurons tend to increase in length, (c) and there is significant branching of both dendrites and axon collaterals of individual neurons. These physical changes in the neural structures within the brain make possible increases in brain functions that correspond directly to the periods of rapid brain growth.

According to Epstein (2003), the first period of rapid brain growth occurs when an individual is 3-10 months of age. During this time, the rapid growth is primarily a function of the maturing of the cerebellum. As the cerebellum matures and become more complicated, the ability of the child to initiate and control motor activities is enhanced. The second period of rapid brain growth, which occurs between 2-4 years of age, involves the maturation of the senses. Vision and hearing abilities increase exponentially during this phase. By the end of this stage, the child can see, hear, taste, touch, and smell virtually on the adult level. The third stage of rapid brain growth, which occurs between 4-6 years of age, is similar to the earlier stages because it is mainly concerned with the gaining of experiences and expertise in the use of newly acquired neural networks. This stage is characterized by refinement of different types of activities (Epstein).

Hardiman (2003) said that it is during this period of a child's development that the production of new neurons essentially comes to a halt. If no new neurons are produced during this stage, what accounts for the increase in brain size? The answer lies in the assumption that existing neurons create additional and progressively more complex synapses within the developing brain. This increase in complexity allows the merger of previously separate mental functions. The result is an increase in concrete-reasoning ability and abstract sensorimotor capabilities.

Sousa (2001) noted that these periods of rapid brain growth align themselves well with the jumps in cognitive abilities that were described by Piaget. It is reasonable to assume that these newly displayed functions are not solely genetic. If this were the case, then all children would display these concrete-reasoning functions at the same time. There must be a dependence on some modification process in order for this to occur. This represents the first indication that humans are dependent on instruction for the acquisition of the higher cognitive functions.

Epstein (2003) said the fourth stage of rapid brain growth, which occurs between 8 and 10 years of age, is important for two reasons. First, during this period, significant differences occur in the growth of female brains and male brains. During this period, female brains tend to increase in size by a factor of 2 when compared to male brains.

What effect does this have on the difference between boys and girls? Epstein said that most research indicates that it is at this stage of development that there is large increase in right-brain growth. This is significant in the context of education. Second, during this period, concrete functions merge with sensorimotor functions. This may explain why girls are somewhat more advanced athletically at this age than boys.

The fifth stage of rapid brain growth described by Epstein (2003), which occurs from 14-16 years of age, was the most relevant to this applied dissertation research. At this stage, the brain growth of males catches up with brain development of females. Interestingly, this brain growth in males tends to be primarily on the left side, providing for greater mathematical abilities. The 8th- and 10th-grade students who participated in this applied dissertation research study were in this stage of development.

Cooperative Learning in the Classroom

Lord (2001) said, "Over that last few decades, there have been numerous studies supporting or repudiating cooperative learning as an effective means of instructing high school and college students" (p. 30). In general, those in favor of cooperative approaches refer to the advantages of better understanding, longer retention, and more complex thinking on the part of students. On the other hand, opponents of the use of cooperative techniques in the classroom point to concerns that cooperation is too time-consuming, too informal in its approach, and not specific in dictating responsibilities. Lord's review of over 300 studies indicated that only 8% of the articles contained negative reports concerning cooperative education. Because the vast majority of the research indicates positive outcomes for cooperative education, it is reasonable to conclude that the use of cooperative education is a viable instructional strategy in today's classrooms.

In order to describe the use of cooperative learning in the classroom accurately, a working definition needs to be established. Garfield (1993) proposed several definitions. She defined cooperative learning as "an activity involving a small group of learners who work together as a team to solve a problem, complete a task, or accomplish a common goal" (p. 21). In this definition, emphasis is placed on the group as a team, and all members of the team working towards a common goal. Garfield added, "Cooperative learning also falls in the more general category of 'collaborative learning,' which is described as working in groups of two or more, mutually searching for understanding, solutions, or meanings, or creating a product" (p. 21). The emphasis is on differentiating between cooperative learning and collaboration; it is clear that cooperative learning is a subset of collaboration. Garfield also described what cooperative learning is not:

> It is not having students sit side-by-side at the same table and talk with each other as they do their individual assignments, having students do tasks individually with instructions that those who finish first are to help slower students, or assigning a report to a group where one student does all of the work and the others put their names on it. (p. 21)

Other authors have echoed the idea that cooperative learning involves the formation of groups in which individuals work toward a common goal. Tabak et al. (1995) described cooperative learning as "students working together, serving as learning resources for each other, to pose questions, plan investigations, gather and interpret observations, and construct models" (p. 1251). In a successful cooperative learning environment, students actually teach each other, which results in two benefits. First, students who do not pick up concepts as quickly as their classmates are given the opportunity to learn from their peers. Second, students who take on the role of "teachers" often gain a deeper understanding of the concepts taught. Gokhale (1995) stated, "Collaborative learning refers to an instruction method in which students at various performance levels work together in small groups toward a common goal" (p. 22). This definition addresses another aspect of cooperative learning: the merging of students with different performance levels.

Towns, Kreke, and Fields (2001) wrote,

> These recommendations are aligned with the notion that each student has a preferential learning style--that human individuality guarantees that the learning process is not the same for all students. To attract and retain a more diverse population of students in science, mathematics, engineering, and technology courses, faculty must acknowledge and act upon variations in student learning styles. Whether the groups solve problems, perform open-ended laboratories, give presentations, or prepare for quizzes or exams, discussing information in a group requires students to be more active in their learning. (p. 111)

This component of cooperative learning was of special interest to this researcher. Although there is a plethora of reasons to utilize cooperative education, few researchers have explored ways to form the effective learning groups.

Cooperative learning is a method for increasing students' achievement and levels of learning. An aspect of cooperative learning that has been overlooked up to this point is the interaction that occurs among students. Positive outcomes from cooperative learning scenarios can only be accomplished if the group members encourage and facilitate each other's learning efforts. Garfield (1993) wrote, "Positive interdependence can be promoted by careful design and monitoring of group activities" (p. 23).

How to form groups and how the individuals in a group interact were the foci of this research study. Because the use of Browning's (2006) Emergenetics® model in the field of education is in its infancy, no studies could be found that directly assessed the use of this model to form groups in an educational setting. However several studies have been conducted on the use of groups in laboratory settings and its impact on student achievement. Orehowsky (1999) studied the effects of laboratory-based instruction and assessment on high school students' acquisition of chemical facts and principles and their attitudes about science and science laboratories. Although Orehowsky's research indicated a positive correlation between laboratory experiences and student achievement, no attempt was made to group students using any method other than random selection.

Moody's (1990) investigation of the relationship between laboratory experience and student achievement included laboratory group formation as a variable. The formation of the laboratory groups involved assessment of students' formal reasoning ability. The results of Moody's study indicated that group formation is an important technique that has an effect on students' achievement levels. There is obviously more room for research in this area.

Inquiry Skills in the Laboratory

The National Science Teachers Association (n.d.) and the Georgia Department of Education (n.d.) recommended that students in high school science courses spend at least 40% of their time in laboratory activities, but these organizations did not suggest what types of laboratory exercises should be included in the curriculum. The standards of the National Research Council (1996) call for the use of inquiry-based activities in science classrooms at all levels. In these standards, the term *active process* is used to imply both physical and mental activities. Hands-on activities are not enough; students must also have "minds-on" experiences. Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers. In laboratory settings, students establish connections between their current knowledge of science and the scientific knowledge found in many resources; they apply science content to new questions; they engage in problem solving, planning, decision making, and group discussions; and they experience assessments that are consistent with an active approach to learning (Bybee & Champagne, 1995).

For years, teachers have struggled to find methods within their classrooms to increase the levels of student reasoning and improve their use of thinking skills. Science knowledge is of little use unless it is accompanied by the ability to use that knowledge for thinking and reasoning. Inquiry is not a specific teaching model or curriculum model. The promotion of inquiry within classrooms is determined by individual teachers. Teachers are expected to create different modes for increasing inquiry skills in their individual classrooms. Differences in local environments, such as teacher knowledge, student age, and language proficiency, necessitate that the implementation of inquiry programs is individualized (Keys & Bryan, 2001).

Discussing inquiry as a method of teaching science, Bybee and Champagne (1995) wrote,

> The basis of students formulating science concepts and abilities, as well as coming to understand the nature of science, is through active involvement and investigations. This implies that students will engage in inquiry, identify questions and concepts that guide investigations, and design investigations. They will also use critical thinking and logic to make connections between evidence, science knowledge, and their explanations of phenomena. (p. 43)

In this definition of inquiry, the idea of fostering reasoning and thinking abilities is foremost, and the active involvement of students in scientific investigation is essential.

Germann, Aram, and Burke (1996) suggested that scientific thinking logically involves inquiry skills and can be viewed as problem solving. Science reasoning skills involve basic and integrated science process skills that constitute the key elements of inquiry. Germann, Aram, et al. explained, "These skills include posing questions, formulating hypotheses, identifying and defining variables, designing experiments, collecting and transforming data, drawing conclusions, and providing evidence" (p. 80).

Haury (1993) said that inquiry-oriented instruction should engage students in the investigative nature of science. The use of inquiry techniques involves activities and skills, but the focus should be on the active search for knowledge or understanding to satisfy a curiosity. Inquiry involves active participation on the part of the student. The passivity of students sitting in a classroom listening to a teacher lecture for days on end is no longer acceptable in science education. Inquiry models in science education are at their best when they engage students in investigations to stimulate as well as satisfy their curiosities and to provoke wonder. Inquiry involves (a) seeking an answer to a problem, (b) developing a solution for the problem, (c) testing solutions to the problem, (d) explaining the outcomes, and (e) making decisions based on those outcomes.

Nowhere can the inquiry process be better implemented than in the science laboratory. The science laboratory is a place where several important goals and objectives can be achieved. Laboratory exercises have been shown to be important in the achievement of five areas: (a) skill attainment, (b) concept development, (c) evolution of cognitive ability, (d) understanding of the nature of science, and (e) improvement in students' attitudes toward science (Blosser, 1990). The problem, however, is that most commercially available laboratory manuals do not lead to the development of inquiry skills. According to Blosser, most laboratory manuals include exercises that follow a "cookbook" approach (i.e., the students are asked to follow a concrete set of steps, and the end result is to generate a usable set of data). No attempt is made to develop the scientific process skills: (a) identifying a problem, (b) developing hypotheses, (c) identifying variables, (d) designing experiments to test the hypotheses, (e) collecting data, (f) analyzing the data, and (g) drawing conclusions based on the data. The concept of inquiry as a means for learners to investigate the natural world, propose ideas, and explain and justify assertions based on evidence was of interest in this research.

What benefits can be expected from an inquiry-based approach in a science laboratory? A major benefit of the inquiry-based approach in a science classroom, specifically a science laboratory, is the development of problem-solving skills in a methodical, scientific manner through the use of process skills. Leonard (1989) listed the following additional benefits:

1. Inquiry-based laboratory strategies require more student involvement and are more inductive than traditional approaches.

2. Inquiry-based laboratory strategies contain less direction and give students more responsibility for determining procedural operations.

3. Inquiry-based laboratory strategies require students to make more extensive use of science process skills.

4. Inquiry-based laboratory strategies produce significantly greater educational gains than traditional approaches.

5. Inquiry-based laboratory strategies appear to work equally well for students of all ability levels not just the very academically talented.

The last benefit mentioned by Leonard is important because laboratory exercises are primarily performed by groups of students. The effect of groups on the attainment of inquiry skills in science laboratories was the focus of this research study.

There are several drawbacks to the implementation of inquiry strategies into science laboratory exercises. The implementation of a laboratory program designed to increase inquiry skills requires more work on the part of the teacher. For many teachers, it is more difficult to guide students through a laboratory exercise than to instruct them. Commercially available laboratory manuals and programs that are designed specifically for the development of inquiry skills are not readily available. Teachers must adapt existing material to meet the requirements of a true inquiry approach. Not all researchers have been convinced of the benefits of an inquiry-based approach. Blosser (1990) said that many researchers believe that no significant differences have been identified between students who are exposed to inquiry exercises and students who receive direct instruction. Proponents of the inquiry method have argued, however, that many of these studies are superficial and do not contain the necessary follow-up to reach a valid conclusion.

The historical development of brain research with regard to education and the benefits of cooperative learning and inquiry-type laboratory exercises were investigated during this research project. The researcher formed student groups based on the students' responses to Browning's (2006) Emergenetics® profile and studied the effects of the grouping on the students' development of inquiry skills in a science laboratory.

Chapter 3: Methodology

The purpose of this research was to investigate the effects of team formation based on Browning's (2006) Emergenetics® profile on students' attainment of inquiry skills in the laboratory program of an introductory biology class. The researcher hoped to use data that resulted from incorporation of the Emergenetics® model to increase the level of achievement for each student. The school that served as the setting for this study adopted the Emergenetics® model into its curriculum in 2004. At that time, all upper school students, faculty, and staff were assessed with instruments that were developed by Browning. The student version of the instrument contains 108 questions that measure individual's thinking and behavioral preferences. Students were provided with copies of their profiles and required to attend a 2-hour class on how to interpret the profile so they would be familiar with their own thinking and behavioral preferences.

A 12-member committee, known as the Student and Teacher Emergenetics® Profile (STEP™) team was formed. The committee members attended a 2-day workshop that was designed to reinforce the components of the Emergenetics® program from an educational standpoint and to begin planning different ways to implement the program. How the program was implemented was left to the discretion of individual teachers. Discussions among faculty members of the Science Department raised the question of how to improve the laboratory component of the science curriculum. The general belief was that if teachers would deliver lessons that were tailored to students' different thinking preferences, a larger number of students would be reached with each lesson. The researcher believed that if this process were to be continued throughout the students' high school years, the gain in academic achievement would be much greater than if the students' individual thinking preferences were ignored.

Research Design

This research study followed a quasi-experimental, one-group/pretest-posttest design. According to Gall, Gall, and Borg (2003), this type of design has three components: (a) administration of a pretest, (b) application of a treatment (i.e., the independent variable), and (c) administration of a posttest. After pretest and posttest scores are obtained, they are used to determine what effects, if any, were produced by the treatment. In this research, the independent variable was the types of group the students were assigned to based on their individual Emergenetics® profiles (i.e., either a WETeam™ or a LETeam™). The dependent variable was the level of attainment achieved by the students with respect to laboratory inquiry skills as indicated by their pre- and posttest scores.

The quasi-experimental, one-group/pretest-posttest design was chosen for several reasons. Although random assignment of participants is a desirable component in experimental research, it was not feasible in this particular case. Intact classes of approximately 20 students each served as the pool of participants. Because students were assigned to classes by school administrators to satisfy scheduling requirements, the researcher was limited to using the classes as they were arranged. According to Gall et al. (2003), the single-group/pretest-posttest experimental research design is appropriate when the research study has one group of participants and one intervention or treatment. In this research, the one group was composed of all students in an introductory biology course; there was no control group to compare with the experimental group. The elimination of a control group allowed the research to focus on the two types of teams that were formed, WETeams™ and LETeams™.

In this study, the data collected from pretest and posttest scores were analyzed using the Statistical Package for the Social Sciences (SPSS). The SPSS software generated descriptive and inferential statistics. In addition, a one-way analysis of variance was used to determine if the means for the four types of groups within a LETeam™ were equal.

Participants

The participants in this study were 93 students who were enrolled in five introductory biology classes in a small, independent, college preparatory school in West Central Georgia. Demographics of the participants were similar to the demographics of the school's student population in general. The school enrolled 404 male and 418 female students in prekindergarten through Grade 12. The student population was 90.5% Caucasian, 3.03% African American, 0.60% Hispanic, 3.28% Asian American, 1.21% Middle Eastern American, and 1.34% multiracial. Over the past 10 years, the average GPA for graduates was 3.29 on a 4.0 scale, the average Scholastic Aptitude Test score was 1,205, and 70.5% of the students scored 3 or higher on advanced placement exams.

Enrollment in the five introductory biology classes ranged from 17 to 23 students each. Students were assigned to the classes during the summer that preceded the study. Class assignments were determined by scheduling convenience and class size requirements. Introductory biology is a required class; therefore, the classes were composed of students of mixed ability. Of the 93 students who participated in the study, 89 were enrolled in 9th grade, and 5 were enrolled in 10th grade. The average age of the students was 14-16 years. One teacher was assigned to teach all five classes. The researcher was not involved in the teaching of any of these classes.

Instruments

The school in this research study is one of a handful of schools across the nation that has incorporated the STEP™ program into the curriculum. STEP™ is an Emergenetics®-based program that is based on a broad body of current brain and behavioral research (The Browning Group International, Inc., n.d.). This brain development model recognizes that individuals have a combination of genetic tendencies to think and act in certain ways (i.e., nature) that are modified through socialization (i.e., nurture). The STEP™ program leads educators and students through the processes of how individuals think and behave and how these characteristics influence their lives. The program provides students, teachers, and parents with a learning tool that is easy to understand and apply. Using STEP™, teachers and students are able to (a) improve academic performance; (b) build stronger, more creative, and productive learning groups; (c) identify each individual's best learning methods; (d) improve personal relationships; (e) raise personal productivity; and (f) communicate more effectively. The instrument provides students with self-understanding and valuable insights on how they can enhance their own intelligence and make positive changes in their behaviors.

The first phase of the STEP™ program is the assessment of each student using the Emergenetics® profile, which is based on the theory that individuals are born with the genetic propensity to act and think in certain ways and their traits are modified over time as they interact with their environment. This combination of the effects of nature (i.e., genetics) and nurture (i.e., environment) is at the core of the Emergenetics® profile (The Browning Group International, Inc., 2003). In each profile, seven basic sets of attributes are described, four ways of thinking and three ways of behaving. The four thinking attributes are (a) analytical, (b) structural, (c) conceptual, and (d) social. The three behavioral attributes are (a) expressiveness, (b) assertiveness, and (c) flexibility.

The Emergenetics® profile instrument is a self-descriptive, multiple-choice questionnaire. Respondents are asked to answer 108 questions about themselves. Different sets of questions are designed to assess each of the seven attributes. The recommended time to answer the questions is 20 minutes. The score that each individual receives in each of the seven areas depends upon how the individual answers the questions (The Browning Group International, Inc., 2003). The self-descriptive nature of the test raises several concerns that must be noted. First, there is some inherent personal bias in a self-descriptive type of test because how individuals choose to answer questions depends solely on how they perceive themselves, which is not always completely accurate or reliable. Second, the Emergenetics® profile is designed to reveal patterns and does not represent absolutes about an individual. Finally, the concepts of validity and reliability must be considered. These two concepts will be examined separately.

Test validity refers to the degree to which a test actually measures what it claims to measure. According to Hoover (n.d.), “Test validity is also the extent to which inferences, conclusions, and decisions made on the basis of test scores are appropriate and meaningful” (p. 1). With regard to validity, Salvia and Ysseldyke (2004) wrote, “It is the interpretations of test scores required by proposed uses that are evaluated, not the test itself” (p. 145). In this sense, questions of validity are a function of the specific purpose, specific situation, and the specific population involved with the test in question. Salvia and Ysseldyke added, “The process of gathering information about the appropriateness of inferences is called validation” (p. 146). The Browning Group International, Inc. (2003) presented four types of evidence for the validation of the Emergenetics® profile.

Face validity involves only a casual, subjective inspection of the test items to judge whether they cover the content that the test purports to measure (Creswell, 2003). Credibility is directly related to the relevance of the question to whatever it is expected to measure. If test takers view the questions as irrelevant, they will give unreliable answers, and the face validity will be brought into question. Questions on the Emergenetics® profile were specifically written to be relevant to everyday events and behaviors (Browning, 2006).

Content validity is the extent to which a test item actually measures what it is purported to measure. Content validity is somewhat difficult to obtain because it relies on personal feedback from those who agree or disagree that the test describes common thinking or behavioral attributes and on the face validity of its questions. Interviews of participants who have taken the Emergenetics® profile have indicated that the instrument accurately measures both their thinking and behavioral attributes (The Browning Group International, Inc., 2003).

Criterion validity is a measure of how a person's score on a test relates to how the individual will perform in other areas. Many standardized tests are criterion referenced; they are designed to assess the ability of students to perform in other areas. Because the Emergenetics® profile is not designed to be a measure of performance or to predict future success, data concerning criterion validity have not been collected (Browning, 2006).

The final measurement of a test's validity is known as construct validity. Construct validity is a measurement of the extent to which chosen characteristics or traits are actually measured. In most cases, evidence of construct validity depends upon indirect evidence and inference. In the case of the Emergenetics® profile, no attempt was made to evaluate intelligence, emotions, or other psychological aspects. Instead, the profile is designed to get a sense of how individuals prefer to think and behave (Browning, 2006).

Reliability refers to the degree to which a test is consistent and stable in measuring what it is intended to measure. Reliability is analogous to accuracy with other measurement devices. For example, the speedometer in a car is designed to measure the speed of the car in units of distance and time. If the speedometer gives readings that are not consistent and close to the actual speed of the car, the speedometer is not considered accurate. The same is true for assessment instruments. If a test is not considered valid, it does not matter whether it meets reliability standards or not. Of course, the reverse is also true. A test that is not reliable cannot be considered valid.

Reliability also implies that test scores can be generalized. According to Gall et al. (2003), the generalization of test scores can be viewed in three different ways. First, if a test is reliable, similar test questions will produce the same results. Second, test results should be able to be generalized to different time periods. For example, the results of a test taken today should be the same if the test is taken 2 weeks from today. Third, results of a test should not be reliant on the test examiner; the same results should be obtained regardless of who administers the test.

Statistical procedures used in the development of the Emergenetics® profile include inter-item reliability, split-half reliability, and test-retest reliability. Inter-item reliability is the measure of how each particular item correlates to the total score for that item. For example, if a test question is intended to measure flexibility, the value of the responses to this question should correlate positively to the overall score for flexibility. The Emergenetics® profile was culled for questions that did not meet inter-item reliability (Browning, 2006).

Split-half reliability is also a question of correlation. The question is whether there is any relation between scores on the first half of a test as compared to the second half. The measure of split-half reliability used in the Emergenetics® profile is coefficient alpha (Browning, 2006). Salvia and Ysseldyke (2004) reported, “Coefficient alpha is the average split-half correlation based on all-possible divisions of a test into two parts” (p. 126). The Browning Group International, Inc. (2003) reported the following coefficient alphas for the constructs of the Emergenetics® profile: (a) analytical, .83; (b) structural, .76; (c) social, .76; (d) conceptual, .76; (e) expressiveness, .83; (f) assertiveness, .83; and (g) flexibility, .80. A coefficient alpha value of .70 or greater is significant.

The final statistical analysis of reliability for the Emergenetics® profile involved test-retest reliability. Test-retest reliability is a measure of how close a person’s scores on a test are if the individual takes the test again after a period of time. In the development of the Emergenetics® profile, a 2-year time period was used in the determination of test-retest reliability. Results indicated that individuals tended to score in much the same manner over the 2-year period. The Browning Group International, Inc. (2003) reported the following test-retest reliability correlations for the constructs of the Emergenetics® profile: (a) analytical, .84; (b) structural, .87; (c) social, .74; (d) conceptual, .82; (e) expressiveness, .80; (f) assertiveness, .78; and (g) flexibility, .82. Any correlation value of .70 or greater is significant. Based on these data, it is reasonable to conclude that the Emergenetics® profile meets standards of reliability (Browning, 2006).

The Emergenetics® profile meets or exceeds all expected criteria for (a) face validity, (b) criterion validity, (c) construct validity, (d) content validity, (e) split-half reliability, (f) inter-item reliability, and (g) test-retest reliability. The profile provides information regarding four different thinking styles and three behavioral styles using norms generated from the analysis of 10s of thousands of profiles (Browning, 2006).

Laboratory activities as part of a science class have been shown to play an important role in engaging students in science curricula. Hofstein, Nahum, and Shore (2001) wrote, “More specifically, when properly developed, inquiry-centered laboratories have the potential to enhance students’ constructive learning, conceptual understanding, and understanding of the nature of science” (p. 193). Inquiry-type laboratory activities are essential to learning science. Students who are involved in inquiry activities learn the process of (a) conceiving problems, (b) formulating hypotheses, (c) designing experiments, (d) gathering and analyzing data, and (e) drawing conclusions about scientific problems. The science laboratory is a setting in which students work cooperatively in small groups to investigate scientific phenomenon and to participate in unique forms of instruction. The benefits of inquiry exploration in the science laboratory and the use of cooperative learning groups are well documented. Because of these benefits, there has been a large increase in the use of inquiry strategies in laboratories. Doran (1990) said, “As is often true, the program evaluation measures have lagged behind the curriculum development and implementation phases” (p. 42).

There is a prevailing need for a good evaluation instrument to determine if the inquiry approach and the use of groups in the laboratory are effective. Germann (1989) attempted to do just this in his research. Germann wrote, “A valuable tool for research would be an instrument to measure the outcome of various treatments designed to improve the learning of science process skills” (p. 609). The result of Germann’s research was the Processes of Biological Investigations Test (PBIT), which is a 35-question, multiple-choice test that is designed to determine the effectiveness of laboratory strategies for development of inquiry skills (see Appendix A). According to Germann (1989),

This instrument is to be used to measure the effects of various strategies in the

> biology laboratory. Since content independence is not a major concern for this effort, the new instrument, Processes of Biological Investigations (PBIT), was developed using examples taken from biology to measure skill achievement. (p. 610)

The original instrument contained 65 multiple-choice questions. After four revisions, the final result is 35 multiple-choice questions in 12 parts that cover the following seven objectives that were outlined by Germann (1989):

> 1. Hypothesis: to distinguish between possible and improbable or impossible reasons for a problem presented in a short passage.
> 2. Prediction: to distinguish between predictions that are logical or not logical based on a problem presented in a short passage.
> 3. Assumptions: to recognize justifiable and necessary assumptions based upon information presented in a short passage.
> 4. Data and Hypotheses: to distinguish between correct restatement of data and valid hypotheses as the reasons for data presented in a graph.
> 5. Interpretation: to weigh evidence and decide if generalizations or conclusions based upon the data given in tables and graphs are warranted.
> 6. Supporting Data: to determine if data from various experiments support one or another hypothesis based upon a given problem.
> 7. Evaluation: to distinguish between probable and improbable causes, possible and impossible reasons, and effective and ineffective action based upon information presented in a short passage. (p. 615)

The current version of the PBIT was tested using 80 students. The final testing resulted in a mean score of 18.84 and a standard deviation of 6.97. The average difficulty index was 54.50, the average discrimination index was 40.97, the Kuder-Richardson reliability was 0.84, and Cronbach's alpha was 0.86. Germann (1989) wrote,

> The PBIT appears to be a valid and reliable instrument to be used in the biology classroom by teachers and researchers interested in determining the effectiveness of inquiry instruction when the science process skills of formulating hypothesis, making predictions, identifying assumptions, distinguishing data from hypotheses, interpreting data, evaluating supporting data, and evaluating causes are of interest. (p. 616)

The PBIT fit perfectly into the objectives of this research study.

Procedures

The general procedures that were followed in this research study included (a) assessment of the participants with regard to their individual thinking preferences, (b) formation of laboratory groups in each biology class, (c) administration of the pretest, (d) implementation of the laboratory exercise program, (e) administration of the posttest, and (f) data collection and analysis. Each of these steps will be discussed in detail. Before any research began, permission to conduct the study was obtained from the administration of the school.

Assessment of the participants. In the spring of the participants' eighth-grade year, they were administered the Emergenetics® profile on-line through computer facilities at the school. Students who enrolled in the school in their ninth-grade year were administered the assessment upon their acceptance to the school. After each student completed the 108-question instrument, The Browning Group International, Inc. generated an individual thinking and behavioral profile. After all student profiles were generated, each individual profile and class spectrum orders for any selected group were made available to the research school. A spectrum order is a listing of individuals within a group according to their thinking preferences. A sample class spectrum order is included in Appendix B.

Formation of laboratory groups. After the five introductory biology classes were scheduled by the administration of the school, students were placed in laboratory groups based on their individual Emergenetics® profiles and analysis of the class spectrum order. Within each class, an attempt was made to form the "best-fit" WETeam™ or LETeam™ based on the students in each class. A class spectrum order was used to set up the corresponding groups in each class.

When a student was assigned to a laboratory group in a particular class, the student was also assigned an identification number that was coded to indicate whether the student was in a WETeam™ or LETeam™. Additionally, if the student was assigned to a LETeam™, the type of group (i.e., left brain, right brain, concrete, or abstract) was indicated. Student identification numbers were used to identify all participants on the pre- and posttests and during data analysis. Student identification numbers were used to ensure participants' confidentiality and to prevent bias.

The researcher met with each class and explained to the students that they would be participating in a research experiment. Each student was asked to sign a permission form, and because of the age of the participants (i.e., 14-16 years), parental consent forms were also required.

Administration of the pretest. After the researcher collected the necessary permission letters and consent forms, each class of students was asked to complete the pretest PBIT. Each student was provided with an individual copy of the test and a response sheet (see Appendix A). Instructions to the students included (a) the confidentiality of their scores, (b) how scores would be utilized, and (c) an explanation that their scores on the PBIT would not affect their grades in the course. These statements were intended to reduce any anxiety that might occur during the test. After all of the students completed the pretest, the researcher scored their pretest response sheets using the supplied answer key and recorded their scores.

Implementation of the laboratory exercise program. After students were placed in laboratory groups within their individual classes, all of the necessary permission and consent forms were collected, and students had completed the pretest, the laboratory program began. The time period for the research was one semester, which was 18 weeks in length. A laboratory exercise was performed approximately every 2 weeks. This timetable allowed for the completion of seven laboratory exercises. Each of the laboratory exercises for this research was chosen because it had been designed to develop inquiry skills in students. Sample laboratory exercises are displayed in Appendix C. The selection of the laboratory exercises was important because it was imperative that the exercises were designed to teach what was proposed to be measured. Unfortunately, most commercially available laboratory manuals are not designed to implement, develop, and concentrate on inquiry skills. In 1996, Germann, Haskins, and Auls "performed a descriptive study on nine high school laboratory manuals to determine how well they promote the basic and integrated science process skills that are involved in scientific inquiry" (p. 82). Their results indicated that although some of the manuals attempted to include inquiry strategies into the individual exercises, most did not require students to be active investigators.

The laboratory exercises selected for this study were chosen because they required students to (a) pose questions, (b) develop hypotheses, (c) design activities, (d) interpret data, and (e) draw conclusions. Doran, Chan, Tamir, and Lenhardt (2002) stated the intended purpose of a manual is to "focus on performance based assessments that use the science classroom and laboratory as major contexts for inquiry" (p. 7). The specific exercises were selected because of their emphasis on (a) planning, (b) performing, (c) analyzing, and (d) applying. Secondary skills included (a) relating or integrating results to underlying themes or models, (b) proposing additional investigations or hypotheses, and (c) suggesting applications beyond the context of the specific investigation. Students were expected to complete all prelaboratory exercises, the actual laboratory exercises, and all postlaboratory exercises as part of the group to which they were assigned. Students were informed that grades for the laboratory exercises would be partially determined by the extent to which all members of the group participated in the overall process. This policy was intended to ensure the maximum participation of all members of the group and deter students from either not participating or attempting to dominate the group.

Administration of the posttest. Approximately 1 week after the conclusion of the last laboratory exercise, the posttest was administered to all participants. The posttest was administered in exactly the same format as the pretest. After all participants completed the posttests, the researcher scored the response sheets using the appropriate answer key and recorded a score for each participant.

Analysis of the data. Students' pre- and posttest scores were entered into the SPSS computer program, and descriptive statistics were used to answer the first 2 research questions of this study. Gall et al. (2003) defined descriptive statistics as mathematical techniques for summarizing and displaying a set of numerical data. The appropriate descriptive statistics for the single-group/pretest-posttest quasi-experimental research design are means, standard deviations, and variances. In this study, the mean was the average of the pretest and posttest scores for all the members of a particular type of laboratory group. The mean difference for each student was used as an indicator of the extent to which attainment of inquiry skills was increased due to participation in the group.

Standard deviation is defined as the measure of the deviation of the distribution of the scores from the mean. Variance is another measure of the deviation of the distribution of scores from the mean. Inferential statistics used in this research included the *t* test for paired samples. Creswell (2003) defined the *t* test for paired samples as a statistical test with confidence limits for a *t* distribution. This statistical test is used to test hypotheses about means of normal distributions. It is appropriate to employ this type of *t* test when there are two observations or measurements per participant. Because the research design utilized pre- and posttest scores for each participant, use of the *t* test for paired samples was justified.

Statistical significance was determined by applying the decision-making rule using the SPSS generated probability value of .000. The alpha value was set at a conservative value of .05. Additional statistical analysis performed included a one-way analysis of variance to answer Research Question 3. A one-way analysis of variance is appropriate for comparing means of three or more samples or treatments to avoid the errors that are inherent in *t* tests.

Limitations

Gall et al. (2003) wrote, “The key problem in experimentation is establishing suitable controls so that any change in the posttest can be attributed only to the experimental treatment that was manipulated by the researcher” (p. 367). Factors that could not be controlled by the researcher during this study were as follows:

1. The fact that participants were not randomly assigned to the particular classes prevented the researcher from utilizing a true experimental design.

2. Previous achievement level or ability in science inquiry was not a criterion for students’ assignment to the instroductory biology classes.

3. Because the pretest and the posttest were the same instrument, there was the possibility of students becoming “test-wise.” This phenomenon is common when two tests are similar enough that students show improvement simply because of their prior experience with the test.

4. True WETeam™ or LETeam™ laboratory groups could not be formed due to the limited number of students assigned to each introductory biology class.

5. Because the research was conducted on a small sample of students in a small, independent, college preparatory school, the ability of the researcher to generalize the results to other settings is limited.

6. It was possible that the students would improve due to the fact that they were aware that they were participating in an experiment. This situation, which is referred to as the Hawthorne effect, may have affected the results.

7. The measurement of the dependent variable, inquiry skill attainment, was dependent on the ability of the selected instrument to measure what it claims to measure.

8. There was also a possibility that students would enter or leave the program during the experimental phase, which would have an effect on the groups; however at the school, the student population was very constant. It was rare for students to leave or enroll in the middle of a semester.

Delimitations

Delimitations establish the boundaries, exceptions, reservations, and qualifications that are inherent in every research study (Creswell, 2003). Specifically, delimitations are used to narrow the scope of a study. In this study, the following delimitations were present:

1. The research was limited to the students who were enrolled in introductory biology classes.

2. The research concentrated on the effects that group formations based on students' thinking preferences had on their attainment of inquiry skills. Although Browning's (2006) Emergenetics® profile includes the behavioral preferences of assertiveness, expression, and flexibility, these attributes were not considered in this research.

3. Although there may be differences in the thinking preferences of males and females, this research did not address gender differences.

Chapter 4: Results

The purpose of this research study was to investigate the effects of team formation that was based on students' thinking and learning preferences on their attainment of inquiry skills in an introductory biology laboratory program. Participants in the study were 93 students who were enrolled in five intact introductory biology classes at a private, college preparatory school. In August of 2006, the researcher obtained class rolls from administrators of the school. These forms identified the students who were enrolled in introductory biology classes for the 2006-2007 school year. Enrollment figures for the five classes were 23, 17, 18, 17, and 19, respectively.

The researcher placed the students who were assigned to each class into laboratory teams based on their responses to Browning's (2006) Emergenetics® profile. A STEP™ spectrum for each class was used to assign students to a particular laboratory team. Five different types of teams were possible: (a) WETeams™, (b) analytical teams, (c) concrete teams, (d) left-brained teams, and (e) right-brained teams. Using the STEP™ spectrum, right-brained or left-brained team members were identified using the formula, (A + T) - (S + C), where A is equal to the student's individual abstract percentile score, T is equal to the student's individual structural percentile score, S is equal to the student's individual social percentile score, and C is the student's individual conceptual percentile score. In this formula, a large positive value is indicative of a primarily left-brain thinker, and a large negative value is indicative of a primarily right-brain thinker.

Similarly, abstract and concrete team members were identified using the formula, (A + C) – (S + T), where A, C, S, and T are the same variables described above. In this formula, a large positive value indicates a primarily abstract thinker, and a large negative value indicates a primarily concrete thinker. Students who were not placed into abstract, concrete, right-brain, or left-brain teams were arranged into WETeams™. Students who were assigned to WETeams™ displayed all four of the thinking preferences. Analyzing the STEP™ spectrum for each intact biology class and using the formulas described above, the researcher formed four left-brain teams, five right-brain teams, five abstract teams, five concrete teams, and seven WETeams™. Each team contained between three and five members.

After obtaining permission from students and their parents, the PBIT was administered to all 93 biology students as a pretest. The pretests were then scored by the researcher, and individual pretest scores were recorded for each student. Following the administration of the pretest, the 26 laboratory teams participated in a program designed to increase students' inquiry skills in the laboratory. The program contained seven laboratory exercises; each exercise took from 1-3 days to complete. A laboratory exercise was performed approximately every 2 weeks. During the 16-week laboratory period, students participated in all prelaboratory activities, laboratory exercises, and postlaboratory discussions and reports by collaborating with their respective team members. Following the conclusion of the laboratory exercises, all students were administered the PBIT as a posttest. The posttests were then scored by the researcher, and individual posttest scores were recorded for each student.

According to Creswell (2003), a single-group/pretest-posttest quasi-experimental research design is comprised of a pretest, an intervention (i.e., the treatment that the participants receive), and a posttest to evaluate the effects of the treatment. Baxter, Shavelson, Goldman, and Pine (1992) indicated that this design is appropriate when there is no control group to compare to the experimental group. The independent variable in this quasi-experimental design was the type of group a student was assigned to during the laboratory program. The dependent variable was the attainment of inquiry skills as determined by the students' scores on the pre- and posttest instrument. The researcher computed descriptive and inferential statistics for all of the groups using the SPSS.

Descriptive statistics were defined by Gall et al. (2003) as mathematical methods for summarizing and displaying a set of numerical data. The descriptive statistics to utilize when reporting for a single-group pretest/posttest quasi-experimental research design are means, standard deviations, and variances for the pre- and posttest scores. It is also appropriate to report the number of participants in the overall group. The mean is the average of all scores, and the standard deviation is a measure of the deviation of the distribution of scores from the mean. Variance, which is the square of the standard deviation, is another measure of the deviation of the distribution from the means.

In addition to descriptive statistics, it is also appropriate in a single-group/ pretest-posttest quasi-experimental research design to compute inferential statistics in order to make inferences about larger populations based on the results of a small population. In this research, the inferential statistical procedure used was the *t* test for paired samples. The *t* test for paired samples is a statistical test that has confidence limits for a *t* distribution. It is used to test hypotheses about means of normal distributions (Creswell, 2003). It is appropriate to employ the *t* test for paired samples when there are two measures per participant.

Results for Research Question 1

The first research question addressed by the study was, How does inclusion in a WETeam™ laboratory group affect students' attainment of inquiry skills? In response to this question, the pretest mean for the 28 WETeam™ members was 19.7, and the posttest mean was 23.4. Table 1 contains additional descriptive statistics.

Table 1

Descriptive Statistics for Thinking Preference Groups, Pretest and Posttest

		Pretest			Posttest		
Group	No.	*M*	*SD*	Variance	*M*	*SD*	Variance
WETeam™	28	19.7	4.21	16.3	23.4	4.71	22.1
LETeam™	65	20.3	4.68	21.7	21.6	3.37	11.4
Left-brain thinking	14	21.6	4.88	24.0	22.4	4.84	23.5
Right-brain thinking	18	19.9	4.81	22.1	21.4	3.09	9.3
Concrete thinking	16	19.1	4.00	17.1	20.4	3.26	11.2
Abstract thinking	17	20.8	5.06	25.3	22.5	2.27	5.5

Note. The maximum score possible was 35. Alpha level was set at .05.

For all 93 participants, the pretest mean was 20.01, the standard deviation was 4.626, and the *t* value was 21.25. The posttest mean was 22.30, the standard deviation was 4.013, and the *t* value was 22.28.

For Research Question 1, the computed *t* value was 5.679, the mean difference was 3.714, and the probability (i.e., statistical significance) was .000 with an alpha value set at a conservative level of .05. Table 2 provides additional information of the inferential statistics computed for this research.

Results for Research Question 2

The second research question in the study was, How does inclusion in a LETeam™ laboratory group affect students' attainment of inquiry skills? In response to this question, the pretest mean for the 65 LETeam™ members was 20.3, and the posttest mean was 21.6 (see Table 1). The computed *t* value was 2.353, the mean difference was 1.3, and the probability (i.e., statistical significance) was .022 with an alpha value set at a conservative level of .05 (see Table 2).

Table 2

Inferential Statistics for Thinking Preference Groups

Group	No.	*M* diff.	*SD*	*t* value	*df*	*p*
WETeam™	28	3.714	3.409	5.679	26	.000
LETeam™	65	1.400	4.722	2.353	63	.022
Left-brain thinkers	14	0.786	5.356	0.481	12	.639
Right-brain thinkers	18	1.611	3.898	1.653	16	.118
Concrete thinkers	16	1.250	4.389	0.972	14	.348
Abstract thinkers	17	1.706	5.497	1.508	15	.152

Note. Diff. = difference. Alpha level was set at .05.

Results for Research Question 3

The third research question in the study was, Within LETeams™, is there a significant difference in students' attainment of inquiry skills in the four different types of groups? To answer this question, descriptive statistics were calculated for each type of LETeam™. The pretest mean for the 14 left-brain team members was 21.6, and the posttest mean was 22.4. The pretest mean for the 18 right-brain team members was 19.9, and the posttest mean was 21.4. The pretest mean for the 16 concrete-thinking team members was 19.1, and the posttest mean was 20.4. The pretest mean for the 17 abstract-thinking team members was 20.8, and the posttest mean was 22.5 (see Table 1)**.**

Inferential statistics were also computed for each type of LETeam™. For left-brain team members, the computed *t* value was 0.481, the mean difference was .786, and the probability (i.e., statistical significance) was .639 with an alpha value set at .05. For right-brain team members the computed *t* value was 1.653, the mean difference was 1.611, and the probability (i.e., statistical significance) was .118 with an alpha value set at .05. Concrete-thinking team members had a computed *t* value of .972, a mean difference of 1.25, and a probability (i.e., statistical significance) of .348 with an alpha value of .05. Abstract-thinking team members had a computed *t* value of 1.508, a mean difference of 1.706, and a probability (i.e., statistical significance) of .152 with an alpha value of .05 (see Table 2).

In addition to the above statistics, a one-way analysis of variance was conducted on the data collected to respond to Research Question 3. A one-way analysis of variance allows the comparison of data for several groups all of which are independent but with possibly different means. A one-way analysis of variance indicates whether all of the means are equal. Appendix D provides the summary data for this one-way analysis of variance.

Chapter 5: Discussion

Introduction

This research was instituted in response to the growing emphasis on student achievement as mandated by current federal legislation and recent advances in brain research that have indicated there are significant differences in how individual students achieve learning. Increasing use of laboratory exercises as a way to develop students' inquiry skills and the expanding use of collaborative groups within schools were other factors that affected the development of this research project. The study was guided by three research questions:

1. How does inclusion in a WETeam™ laboratory group affect students' attainment of inquiry skills?

2. How does inclusion in a LETeam™ laboratory group affect students' attainment of inquiry skills?

3. Within LETeams™, is there a significant difference in students' attainment of inquiry skills in the four different types of groups?

Elaboration and Interpretation of Results

Overall, students in all of the groups that participated in the laboratory program showed positive mean differences between their pretest and posttest scores. This statistic implies that the laboratory program accomplished its intended goal of increasing the attainment of inquiry skills for the participating students.

The statistical results for Research Question 1 showed a mean difference of 3.174, indicating an overall improvement between the pretest and posttest scores for those students who participated in a WETeam™ laboratory group. The WETeam™ laboratory groups had a computed t value of 5.679 and a p value of .000. The decision-making rule to explore statistical significance was applied with a SPSS-generated value of .000. The alpha value used to test Research Question 1 was set at a conservative level of .05. Because the *p* value was less than the alpha value, it can be inferred that the mean difference of 3.174 has statistical significance at the .05 level. This means that there is a 95% probability that the increases in scores between the pre- and posttest can be directly attributed to the students' participation in a WETeam™ laboratory group.

The statistical results for Research Question 2 showed a mean difference of 1.300, indicating an overall improvement between the pre- and posttest scores for students who participated in a LETeam™ laboratory group. Additionally, the LETeam™ laboratory groups had a computed *t* value of 2.353 and a *p* value of .022. The decision-making rule to explore statistical significance was applied with a SPSS-generated *p* value of .000. The alpha value used to test Research Question 2 was set at a conservative level of .05. Because the *p* value was less than the alpha value, it can be inferred that the mean difference of 1.300 has statistical significance at the .05 level. This means that there is a 95% probability that the increases in scores between the pretest and posttest can be directly attributed to the students' participation in a LETeam™ laboratory group.

The statistical results for Research Question 3 were broken down for each particular type of group formed. Left-brain teams showed a mean difference of .786 with a computed *t* value of .481 and a *p* value of .639. Right-brain-thinking teams showed a mean difference of 1.611 with a computed *t* value of .1.653 and a *p* value of .118. Concrete-thinking teams showed a mean difference of .1.25 with a computed *t* value of .972 and a *p* value of .348. Abstract-thinking teams showed a mean difference of .1.706 with a computed *t* value of .1.508 and a *p* value of .152. Although each of the four LETeam™ laboratory groups showed improvement on the posttest over the pretest, each type of group showed a *p* value greater than the alpha value. Because these groups had *p* values greater that the alpha value, it can be inferred that the mean differences, although positive, cannot be attributed to the students' participation in a particular group. It is just as likely that the increase in the mean difference occurred due to chance.

The differences between the four LETeams™ were analyzed with the one-way analysis of variance test. The *F* value for the posttest means for the four LETeam™ groups was 1.91, and the *F* critical value was 2.755. Because the *F* critical value was greater than the *F* value, the null hypothesis that the means of the four groups were not significantly different was confirmed.

Implications of Findings

The original purpose of this research study was to determine whether participation in a particular type of laboratory group had an effect on students' attainment of inquiry skills in an introductory biology laboratory program. Federal legislation, such as the No Child Left Behind Act (U.S. Department of Education, n.d.), and increased use of high-stakes tests have put teacher accountability in the forefront of most educational reforms. The increased pressure on teachers to ensure that each student's learning is maximized requires that teachers have at their disposal the best tools available to accomplish this task. Browning (2006) recommends the STEP™ program as such a tool. Although there may be more uses, there are two important uses that are readily apparent from this research. STEP™ information can be used to individualize instruction by teachers. Recent advances in brain research indicate that although human brains are physically indistinguishable and are constructed and function in the same manner, the hardwiring of each brain produces measurable differences (Genessee, 2000).

The results of this research study indicate that the type of group a student participates in does make a difference in the student's attainment of inquiry skills. The descriptive and inferential statistics collected to answer Research Question 1 provide concrete data on which to base future decisions about how laboratory groups should be formed. Because it is common practice to assign students to groups based on convenience or to avoid behavior problems, teachers often fail to use a valuable tool at their disposal. The formation of WETeam™ and LETeam™ laboratory groups provides students with effective learning situations that are based on the students' individual learning style preferences. Additionally, this technique of group formation can be applied to learning scenarios in the classroom other than the laboratory setting. Group discussions, projects, problem-solving exercises, and remedial exercises can all benefit from the use of STEP™ spectrum data to form groups.

In addition to assessing individual differences among students, teachers can use STEP™ spectrum data to modify their teaching to the class as a whole. It is possible that as the result of normal scheduling, students in a particular class may have a preference for one or more particular thinking and learning style. For example, if a class contains a majority of students who have a preference for concrete thinking, these students would perform best in an environment that centers on predictable situations, defined plans and directions, and a large degree of practicality. If the teacher of this class is an abstract thinker and employs instructional methods that are more consistent with conceptual and analytical types of thinking and learning, it is likely that the teacher will not utilize the best tactics available to maximize the learning of these students.

Limitations

There were three main limitations in this research study. First, the research was limited to 93 students who were enrolled in an introductory biology course and concentrated solely on their attainment of inquiry skills within a laboratory setting. Second, the research concentrated on the effects that group formation that was based on students' thinking preferences had on the students' acquisition of inquiry skills. The behavioral preferences of assertiveness, expression, and flexibility were not considered in this research. Third, although differences exist in the thinking preferences of males and females, this research did not address gender differences.

Recommendations

The researcher makes the following recommendations based on the results of this study:

1. Because the data indicated a statistically significant result for participation in WETeams™, the use of STEP™ spectrums to form laboratory teams should be continued at the school.

2. The concept of the formation of teams using STEP™ spectrums should be expanded to include other disciplines, and appropriate research should be conducted to evaluate the results.

3. More research needs to be conducted on the effects that the behavioral preferences of assertiveness, expression, and flexibility have on student achievement.

4. Additional research needs to be conducted to examine the relationships between student achievement and gender.

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Appendix A

Processes of Biological Investigations Test

Processes of Biological Investigations Test
Sample Questions

Part One: Evaluation

The following questions refer to Bubonic Plague, or Black Death, that killed thousands of people during the Middle Ages. The Middle Ages was a time of feudalism and of kings, lords, knights, and peasants. Only the nobility and the clergy were educated. The vast majority of people had no education at all. The study of chemistry was in its infancy as the chemists of the time tried to change iron and lead into gold. Biological studies were limited to observations that could be made with the naked eye since the microscope had not been invented yet. In physics, Sir Isaac Newton had not yet described the Law of Gravity and astronomers still thought that the sun rotated around the earth.

Sanitary conditions during this period of history were very poor. For example, there was no garbage disposal. People just threw their garbage out onto the street. As a result, there must have been a tremendous number of flies, the rat population must have been very high, as well as other pests and microbes that would have lived off the garbage.

The Bubonic Plague, or Black Death, is a highly fatal disease caused by a microscopic bacterial organism called Bacillus Pestis. It is a disease found chiefly in rats and squirrels and is transmitted from one to another by fleas. However, man is also highly susceptible to this disease, and major outbreaks occurred in the past. The disease is spread among humans when infected fleas from rats or squirrels bite people and infect them with the Bacillus Pestis microorganism.

In 1348, there was an outbreak in Italy, and during the next two years, it killed almost half the population of Europe. In some cities, as much as two-thirds of the population was eliminated. It came back in epidemic proportions every ten years or so. In 1665, at least one-tenth the population of London was wiped out. About 80% of the people affected with this disease died within two or three days. After the epidemic, the disease more or less died out in Europe.

The plague is not a major disease at the present time but it still kills people in parts of Asia and Africa. The Bacillus Pestis is now present in the squirrel population in the Western United States.

Evaluate the possible reasons for the disease dying out in Europe.

1. Most of the people who could catch the disease easily (people who were susceptible to the disease) had already died leaving only those who were resistant to the disease.
   a. A possible factor for the disease dying out.
   b. An improbable factor for the disease dying out.
   c. A factor that cannot be judged as possible or improbable.

2. The rats were all eliminated.
   a. A possible factor for the disease dying out.
   b. An improbable factor for the disease dying out.
   c. A factor that cannot be judged as possible or improbable.

3. In order to protect themselves, people did a variety of things, some of which were somewhat effective, some of which were not. Consulting witches and witch doctors:

a. Might have decreased the chances of getting the plague.
b. Might have increased the chances of getting the plague.
c. Would not have affected the chances much one way or the other.

Part Three: Data and Hypothesis

In this exercise, you will be asked to evaluate several statements to determine if each statement is a restatement of the data presented in the graph or if the statement is a hypothesis or "educated guess" as to the reason for the data.

Use the key below to classify the statements.
Key: A. A logical hypothesis or "educated guess" to explain the data.
B. An illogical hypothesis or "educated guess" because it is actually contradicted by the data.
C. A correct restatement of the results; does not attempt to explain the results with a hypothesis.
D. An incorrect restatement of the results; does not attempt to explain the results with a hypothesis.

7. Lack of oxygen causes an increase in the size of blood vessels and this increases blood flow.
8. At near 100% blood saturation, the rate of blood flow in the dog's leg is lowest.
9. Capillaries contract and reduce blood flow when the percentage of oxygen is high.

Part Four: Interpretation of Data--Table

Photosynthesis is a chemical process that occurs in green plants. Photosynthesis uses carbon dioxide (that enters the leaf through small leaf openings), water from the soil, (that gets to the leaf through conducting cells in the roots and stems), and light energy to make a sugar called glucose. The glucose is then changed into starch for storage.

Six geranium plants were treated in several experiments to test these ideas about photosynthesis.

Plant	Treatment		Results
Plant I	Half of each leaf was covered with aluminum foil to block light.	Placed in light.	Starch is half exposed to light.
Plant II	Upper and lower surface of leaves covered with Vaseline.	Placed in light.	No starch.
Plant III	Placed in jar containing no carbon dioxide.	Placed in light.	No starch.
Plant IV	Leaves removed and placed with stems immersed in glucose solution.	Placed in dark.	Starch, especially along veins of leaves.
Plant V	No treatment	Placed in dark.	No starch.
Plant VI	No treatment	Placed in light	Starch

Use the following key to classify the statements below.
Key: The interpretation of the data is:

A. Supported by the data.
B. Rejected on the basis of the data presented.
C. Logical, but the experiment is not designed to test it.

10. Light is necessary for starch formation in plants.
11. This experiment lacks a control.
12. The roots of a plant may store starch.

Part Seven: Supporting Data

The pancreas is an organ of the human body that secretes digestive enzymes into the intestines. This enzyme is normally secreted when food is about to enter the intestine. Scientists wondered what caused the enzyme to be secreted at the right time.

The two hypotheses below are possible explanations of the control of pancreatic secretions into the intestine.

I. Nerves stimulate the pancreas to secrete its enzyme into the intestine.
II. A hormone secreted by the intestine into the blood causes the pancreas to secrete its enzyme into the intestine.

Use the key below to classify each of the following experiments as they relate to the hypothesis.

Key:
A. Supports hypothesis I only.
B. Supports hypothesis II only.
C. Supports both hypotheses.
D. Supports neither hypothesis.

19. When a nerve leading to the pancreas is stimulated, the pancreas secretes enzymes.
20. If the nerves leading to the pancreas of a hungry dog are cut, no enzymes are secreted by the pancreas.

Part Eight: Interpretation of data--Table

During the function of the kidneys, the liquid part of the blood called plasma is forced through special filtering structures. This forms a filtrate in the kidney tubules. As the filtrate passes through the kidney tubules, water and other beneficial materials are removed and reabsorbed into the plasma of the blood, leaving a solution of waste materials called urine in the kidney tubules.

The next three questions are based on the following data.
Composition of Plasma, Filtrate, and Urine (g/100 ml fluid)

Component	Plasma	Filtrate	Urine
Urea	0.03	0.03	2.00
Uric acid	0.004	0.004	0.05

Glucose	0.10	0.10	0.00
Amino acids	0.05	0.05	0.00
All salts	0.72	0.72	1.50
Proteins	8.00	0.00	0.00

Use this key to classify the statements below.

Key: A. A reasonable interpretation of the data.
B. An interpretation contradicted by the data.
C. There is insufficient evidence to make an interpretation.

21. Glucose is not found in urine.
22. The concentrations of all salts is about double in the urine.
23. Uric acid is the most abundant component in the urine.

Part Nine: Hypothesis

Mrs. Potter gave identical ivy plants to both Mrs. Gardiner and Mrs. Bellefleur. Both plants were the same size, had been cut from the same parent plant, and were potted in the same size pot with the same kind of soil. Despite her best efforts, Mrs. Gardiner's plant died a month later while Mrs. Bellefleur's flourished.

Use the key below to evaluate reasons for the death of Mrs. Gardiner's plant.

Key: A. Possible reason.
B. Improbable or impossible reason.

24. Mrs. Bellefleur's plant was of a hardier variety than Mrs. Gardiner's.
25. Mrs. Gardiner's plant became too root bound (the pot was too small for the root system).
26. Mrs. Gardiner's house was too cool for this kind of plant.

Part Ten: Prediction

The water flea is a shrimp-like organism called Daphnia. Water very low in oxygen concentration causes Daphnia to become red, while water high in oxygen concentration causes them to become colorless.

The plasma of red Daphnia is red, while the plasma of the colorless Daphnia is colorless. Analysis shows the red pigment to be hemoglobin.

Scientists know that in humans, oxygenated hemoglobin is bright red; non-oxygenated hemoglobin is dark red; carbon-monoxide hemoglobin is bright cherry red, brighter and lighter than oxygenated hemoglobin.

Scientists also know that carbon monoxide combines with hemoglobin and prevents oxygen from being attached to the molecule.

Problem: What will happen if carbon monoxide is bubbled through the water in which Daphnia are kept?

Use the key below to classify the following predictions.

Key: A. A prediction which is logical on the basis of the above data.
B. A prediction which is not logical; it is contrary to some or all the above data.
C. A prediction which may be logical but for which there is not basis in the data above.
D. Not a prediction; it is a restatement of the given data.

27. Oxygen causes breathing rate to get faster.
28. The plasma of the red Daphnia will appear blue.
29. Hemoglobin is the red pigment in the red Daphnia.

Part Eleven: Interpretation

Scientists were attempting to determine what substances controlled the growth of plant tissues. Three substances were thought to be effective in promoting growth: DPU, CH, and CCM. The following table summarizes the results of their experiment.

Effect of DPU, CH, and CCM on the growth of carrot tissue cultures.

	Fresh weight, mg	Cell number (X 1000)
Plain medium	7.2	45
Plain medium + DPU	9.4	50
Plain medium + CH	29.4	201
Plain medium + CH + DPU	56.8	508
Plain medium + CH + CCM	294	2662

Use the key below to classify the following statements.

Key: The statement is:

A. A reasonable interpretation of the data.
B. An interpretation contradicted by the data.
C. There is insufficient evidence to make an interpretation.

30. DPU is slightly effective.
31. CCM is the control for this experiment.
32. CCM and DPU together are not effective in producing cell growth.

Processes of Biological Investigations Test Response Sheet

Date:________________________________
Student ID number:_____________________
Pretest/Posttest (circle one)
Directions: For each question on the Processes of Biological Investigations Test, circle the best answer below.

Question	Answer	Question	Answer	Question	Answer
1.	A B C D	13.	A B C D	25.	A B C D
2.	A B C D	14.	A B C D	26.	A B C D
3.	A B C D	15.	A B C D	27.	A B C D
4.	A B C D	16.	A B C D	28.	A B C D
5.	A B C D	17.	A B C D	29.	A B C D
6.	A B C D	18.	A B C D	30.	A B C D
7.	A B C D	19.	A B C D	31.	A B C D
8.	A B C D	20.	A B C D	32.	A B C D
9.	A B C D	21.	A B C D	33.	A B C D
10.	A B C D	22.	A B C D	34.	A B C D
11.	A B C D	23.	A B C D	35.	A B C D
12.	A B C D	24.	A B C D		

Note. From “Processes of Biological Investigations Test,” by P. J. Germann, 1989, *Journal of Research in Science Teaching*, 26, pp. 616-624. Copyright 1989 by John Wiley and Sons. Reprinted with permission.

Appendix B

Sample of Class Spectrum Order

		Percentile				Pie-Percent				Composite	
Student	PREF	ANA	STR	SOC	CON	ANA	STR	SOC	CON	ABS-CON	LEF-RIT
1	1AT**	95	78	29	20	43	35	13	9	8	-124
2	1AT**	95	95	44	34	36	35	16	13	-10	-112
3	2ATS*	75	95	85	57	24	30	27	18	-48	-28
4	2AT*C	95	95	82	95	26	26	22	26	13	-13
5	4*TS*	20	95	39	11	12	58	24	7	-103	-65
6	4*TS*	46	57	74	38	21	27	34	18	-47	9
7	5*T*C	39	85	61	87	14	31	22	32	-20	24
8	5*TSC	28	95	85	92	9	32	28	31	-60	54
9	6**SC	39	40	77	52	19	19	37	25	-26	50
10	6***C	30	12	22	95	19	7	14	60	91	75
11	6**SC	36	11	85	44	21	6	48	25	-16	82

Report Summary: for 11 Participants

	ANA	STR	SOC	CON
Number	4	8	6	6
Percent	36	72	54	54

Note. Pie-Percent = percentage (out of 100) for each of the four thinking types; PREF = preference; ANA = analytical; STR = structural; SOC = social; CON = conceptual; ABS-CON = each individual's ranking on a sliding scale from abstract thinking (positive score) to concrete thinking (negative score); LEF-RIT = each individual's ranking on a sliding scale from left-brained thinking (positive score) to right-brained thinking (negative score); AT = an individual with preferences for analytical and structural thinking; ATS = an individual with preferences for analytical, structural, and conceptual thinking; TS = an individual with preferences for structural and social thinking; TC = an individual with preferences for structural and conceptual thinking; TSC = an individual with preferences in structural, social, and conceptual thinking; C = an individual with only conceptual thinking as a preference; SC = an individual with preferences for social and conceptual thinking. This sample form, which contains fictitious information, is reprinted with permission of The Browning Group International, Inc.

Appendix C

Sample Laboratory Exercises

Lab 1 Sowbug Habitats
Student Task Sheet

Task: In this exercise, you will be conducting an experiment to determine what types of environment sowbugs prefer. Sowbugs are crustaceans and close relatives of crabs and lobsters. Like their relatives, sowbugs use gills for respiration. But, unlike most crustaceans, they live on land and not in the water.

Materials:

Beaker of water	eyedropper
Scissors	clock/timer
Paper towels	masking tape
Black construction paper	1 petri dish with 10 sowbugs
1 extra petri dish lid	

Directions:

Part A

1. Answer questions 1-2 on the answer sheet attached

Part B.

1. Using the extra petri dish lid as a pattern, trace two circles on a piece of paper towel
2. Cut out the two circles. Fold each circle in half. Saturate on folded circle with water. It should be moist, but not wet. The second folded circle should remain dry.
3. Arrange the folded circles in the extra petri dish to create a habitat that is half moist and half dry.
4. Remove the lid from the petri dish containing the sowbugs and replace it with the wet/dry habitat lid you prepared.
5. Invert the petri dish so the wet/dry lid becomes the bottom and petri dish becomes the top.
6. Using black construction paper, cover the moist side of the petri dish to make it dark.
7. Note the time on your clock, or start your timer now. Record your start time in the data table on your answer sheet.
8. The sowbugs should remain undisturbed for five (5) minutes. While you are waiting, check your answers to questions 1-2.
9. At the conclusion of the five-minute time period, record the time and location of the sowbugs in the data table on your answer sheet.
10. Complete the remaining questions in Part B of the lab.

Sowbug Habitats
Answer Sheet

Part A

1. Using complete sentences, predict what you think the sowbugs will do if they are released into a habitat with different areas of moisture and light.
2. Using complete sentences, explain why you think the sowbugs will be arranged in the way you predicted.

Part B
Data Table

Start time __________ Stop time __________

Environment	Number of Sowbugs
Moist/Dark	___________________
Dry/Light	___________________

3. Did the animals prefer one environment to another? State evidence for your answer in complete sentences.
4. For this question, answer either (a) or (b).
    a. If most of the animals were found on the dark, moist side of the container, is this proof that sowbugs prefer a moist environment to a dry one? Explain your answer in complete sentences
    b. If most of the animals were found on the illuminated, dry side of the container, is this proof that sowbugs prefer light to darkness? Explain your answer in complete sentences.
5. Based on the way this experiment was run, can you say the sowbugs behavior was due to differences in the light conditions alone? Answer yes or no.
6. Using complete sentences, explain your answer to question 5.
7. How can variables in this experimental setup be changed to allow for better conclusions to be drawn? Answer in complete sentences.
8. For this question, answer either (a) or (b) depending on your results.
    a. If there is a preference, how does it relate to sowbugs survival? In other words, how do the environmental factors of light/dry or dark/moist make it possible for sowbugs to be better able to survive?
    b. If there is no preference, explain why this is the case in terms of sowbug survival and life processes.

Lab 2 Perspiration and Cooling
Student Task Sheet

Task: Collect and analyze data on perspiration.

Materials per student:

2 test tubes	hot water in Styrofoam cups	timer or clock
eye dropper	paper towels	test tube rack
newspaper strips	room temperature water	thermometer
4 rubber bands	funnel	

Background:
When you get hot you perspire, and this is your body's way of maintaining normal temperature. But how effective is perspiration in maintaining your body temperature?

Directions:

1. Examine the apparatus at the laboratory station.
2. Place the test tube rack on a paper towel. Prepare your test tubes by wrapping each one with a strip of newspaper. Use two rubber bands to hold the paper on the test tubes.
3. Quickly fill both test tubes with hot water. Take care not to spill any water on the newspaper.
4. Place one thermometer in each test tube. Record the starting temperature for each test tube on a data table. In the next step, one test becomes the "wet" test tube and one becomes the "dry" test tube.
5. Use the eyedropper to quickly wet the newspaper of one of the test tubes with room temperature water. The newspaper on the test tube should be completely saturated with water.
6. Measure the temperature in each test tube at intervals of one minute for the next 12 minutes, and record your measurements in a data table you construct.
7. Construct a line graph of your data, and answer questions 8-13.
8. From your data table, what is the temperature of the water in both tubes at 6 minutes?
9. From your graph, what is the temperature of the water in both tubes at 9.5 minutes?
10. Use your graph to predict what the temperature would be in the dry tube after 15 minutes. Using complete sentences, suggest and explanation for your prediction.
11. Using complete sentences, describe and compare the cooling patterns of the two test tubes.
12. Using complete sentences, explain what causes the differences in water temperature between the water in the two tubes.
13. Using complete sentences, describe what comparison you can make between the effect of perspiration on the skin of the human body, and the newspaper on the wet test tube. Relate your answer to body temperature control.

Lab 3 | Respiration
Student Task Sheet

Part A
Time: 30 minutes

Materials:
General:

1 beaker	graduated cylinder
8 test tubes	8 clean stoppers for the test tubes
test tube rack	test tube holders
adjustable hot plate	paper towels
graph paper	thermometer
wax marking pencil	

Special:
- Microorganisms in suspension
- Methlylene blue solution, 40 ml in plastic dropper bottles
- pH solutions of 4, 6, 8, and 10 in dropper bottles

Introduction:
This laboratory exercise presents a problem. Your task in Part A is to plan and design an experiment to solve the problem. You have 30 minutes to complete Part A. At the end of the 30 minutes, your answer sheet will be collected. You will then receive separate directions for Part B. In Part B you use materials and equipment provided in the laboratory kit to collect experimental data for this problem. Write your plan on your answer sheet.

Problem:
Sometimes biologists use indicators to test the effect of various factors on chemical reactions. Your problem is to design an experiment to test the effect of various pH levels on the rate of respiration in microorganisms, using methylene blue as an indicator. Methylene blue is an oxygen indicator. When oxygen is present, it remains blue. When oxygen is absent, it loses its blue color. There may remain a blue ring at the upper edge of the test tube. Design an experiment to test the effect of various pH levels on the rate of respiration in the organism.

a. State a HYPOTHESIS for this investigation as to the effect that various pH levels may have on the rate of respiration in organisms.
b. Under the heading PROCEDURE list in order the steps you will use to solve the problem. You may include a diagram to help illustrate your plans for the experiment. Include any safety procedures you would follow.
c. Construct a DATA TABLE or indicate any other method that you can use to record the observations and results that will be obtained.

Note: In Part A you are <u>NOT</u> to proceed with any part of the actual experiment. You are just to plan and organize a way to investigate the problem.

Part B.
Time 50 minutes

You have 50 minutes to complete this part. Record your work for part B on your answer sheet under the appropriate headings. Perform the experiment by following the steps outlined in the procedures listed below. Under the heading RESULTS record your observations and measurements for the experiment. Use written statements, descriptive paragraphs, tables of data, and/or graphs where appropriate. Construct a GRAPH that presents the relationship between the data you have collected. Under the heading CONCLUSIONS write an interpretation of your results. State the effect that pH level has on respiration of microorganisms. At the end of 50 minutes, your answer sheet for Part B will be collected.

Procedure:

1. Check the temperature of the water in a water bath in a 800 ml beaker (on a hot plate). The temperature must be between 35^{o}C and 39^{o}C. Record the temperature on your answer sheet.
2. Prepare 4 test tubes each with 5 ml of the microorganism in suspension, and 4 test tubes each with 5 ml of distilled water (for the control). Use the marking pencil to label each test tube with a number from 1 to 8.
3. Place 5 ml of prepared pH solutions in each test tube according to the chart below. The pH in each test tube should be as follows:

Microorganism suspension		Control: distilled water	
Test Tube #	pH	Test Tube #	pH
1	4	5	4
2	6	6	6
3	8	7	8
4	10	8	10

Note: Thoroughly rinse the graduated cylinder after filling each test tube.

4. Now add two drops of methylene blue to each test tube (1 through 8). Place the stoppers on each test tube. Mix by carefully inverting each test tube several times.
5. Place test tubes 1 through 4 in the water bath. Record the time at which you placed the test tubes in the water bath on the answer sheet. Observe how long it takes for the blue color to disappear in each test tube. Record the times in a data table. Continue timing for 10 minutes.
6. Take test tubes 1 through 4 out of the water bath and place in the test tube rack. Invert each tube several times. What do you observe? Record your observations in your data table.
7. Repeat steps 5 and 6 for test tubes 5 through 8.
8. Enter the RESULTS (your times and observations) in your data table.
9. Construct a GRAPH of your results.
10. Based on your data and your graphing of the results, write your CONCLUSION about how pH affects the time for the indicator to change.

Lab 4 | Using Indicators
Student Task Sheet

Introduction:
This laboratory test presents a problem, lists materials, and outlines the sequence to be followed in solving the problem and writing your observations and conclusions. You will have a total of 40 minutes to complete this test. Record your answers on a separate sheet of paper.

Problem:
Biologists often use indicators to identify the properties of an unknown substance. Your problem is to conduct an experiment to determine which organic compound is present in the dropper bottle marked UNKNOWN.

Materials:
4 dropper bottles each with 50 ml solutions and labeled SUGAR, STARCH, PROTEIN, AND UNKNOWN.
dropper bottles of Iodine solution, Biuret solution, and Benedict's reagent.
250 ml water bath
hot plate
6 clean, labeled test tubes
test tube holders
test tube rack
goggles
paper towels

CAUTION: SAFETY GOGGLES MUST BE WORN AT ALL TIMES DURING THIS EXERCISE. BIURET REAGENT CAUSES SKIN BURNS. FLUSH WITH WATER IF CONTACT IS MADE WITH THE SKIN.

Record your work on the answer sheet under the appropriate headings.
a. Perform the experiment by following the steps outlined in the procedure below.
b. Under the heading RESULTS record the findings of the experiment. Use statements, descriptive paragraphs, and measurements where appropriate.
c. Under the heading CONCLUSION give an interpretation of your results. What was the unknown? What was your evidence for this identification?
d. At the end of 40 minutes, your papers will be collected.

Procedure:
1. Start your water bath. It needs to be boiling for the test procedure.
2. Transfer 2 ml (50 drops) of the sugar solution to a clean test tube labeled A and add 2 ml of Benedict's reagent. Heat for 2 minutes in the water bath. Record your observations in Table A.
3. Transfer 2 ml of the protein solution to a clean test tube labeled B and add Biuret reagent one drop at a time until a change is noted. Record your observations in Table A.

4. Transfer 2 ml of the starch solution to a clean test tube labeled C and add iodine solution one drop at a time until a change is noted. Record your observations in Table A.
5. Take the unknown solution and transfer 2 ml to each of the three test tubes numbered 1, 2, and 3.
    a. Add 2 ml of Benedict's reagent to test tube #1 and heat for 2 minutes. Record your observations in Table B.
    b. Add Biuret reagent, one drop at a time to test tube #2. Record your observations in Table B.
    c. Add iodine solution one drop at a time to test tube #3. Record your observations in Table B.

Using Indicators
Student Answer Sheet

Table A: Standard Solutions

Test Tube	Solution	Observations
A	Sugar	
B	Protein	
C	Starch	

Table B: Unknown Solutions

Test Tube	Indicator Used	Observations
1	Benedict's	
2	Biuret	
3	Iodine	

Results:

Conclusions:

Lab 5 Diffusion/Osmosis
Student Task Sheet

Introduction:
This laboratory test presents a problem. Your task is to plan and conduct an experiment to solve the problem.

Problem:
Osmosis is a process by which substances enter and leave cells across a semi-permeable membrane. Your problem is to design and experiment to test the effects of two variables (time and concentration) on diffusion of potassium permanganate into potato cube.

Materials:

2 firm potatoes
stopwatch/clock
metric ruler
3 small beakers
1%, 5%, and 10% potassium permanganate solutions in beakers
paper towels
forceps
scalpel
graph paper
waste container

a. State a HYPOTHESIS for this investigation that can be used to test the effects of time and concentration on osmosis.
b. Under the heading PROCEDURE list in order the steps you will use to solve the problem. You may include a diagram to help illustrate your plans for the experiment. Include safety precautions you would follow.
c. Construct a DATA TABLE or indicate any other method that you can use to record the observations and results that will be obtained.
d. Perform the experiment by following the steps outlined in your procedure.
e. Under the heading RESULTS record your observations and measurements for this experiment. Use written statements, descriptive paragraphs, tables of data, and/or graphs where appropriate.
f. Construct a GRAPH that presents the relationship between the distance $KmnO_4$ moved into the potatoes and time and concentration.
g. Under the heading CONCLUSIONS write an interpretation of your results. State the effects of time and concentration on osmosis.

Lab 6 Vitamin C Testing
Task Information

Background:

This task involves vitamin C. Vitamins, and in particular vitamin C have generated a great deal of controversy in our health care. There have been numerous claims for the role of vitamin C in our health, from the prevention of the common cold to a possible cure for certain forms of cancer (vitamin C is a water soluble antioxidant on account of its high reducing power). Many of these claims appear in “mass-market” publications and are often based on anecdotal evidence.

Most vertebrates synthesize vitamin C from their diet. Humans and monkeys are the exception; they do not have the capability to synthesize vitamin C from glucose as they lack the enzyme gulonolactone oxidase. Vitamin C participates in a number of oxidation reactions, including the hydroxylation of proline to hydroxyproline and of lysine to hydroxylysine. As such, synthesis of collagen is comprised of in vitamin C deficiency. Collagen is a protein necessary for the formation of connective tissue in the skin, ligaments, and bones. Vitamin C also helps connective tissue form during the healing of wounds and in the growth and repair of tissues. Other functions of vitamin C include aiding in red blood cell formation, preventing hemorrhaging, and fighting bacterial infections. Vitamin C also participates in the synthesis of carnitine, tyrosine, adrenal hormones, leukocyte functions, and folate metabolism.

The Recommended Daily Allowance (RDA) of vitamin C is 75 mg/day for females and 90 mg/day for males. Smokers suffer increased oxidative stress and metabolic turnover of vitamin C, and the recommended intake is increased by 35 mg/day in both male and female smokers to decrease the effects of reactive oxygen.

In this task on vitamin C, you have an opportunity to use your science knowledge, apply your inquiry skills, and gain more insight into a popular vitamin.

Part A

In this part of the investigation, you will analyze the vitamin C content of orange juice. This task can be completed in one class period of 45 minutes. It gives you an opportunity to manipulate materials and equipment, and learn science concepts necessary for you to design your own experiment in the second part of the investigation.

Task:

You are provided with appropriate materials and equipment to:
Measure and compare the vitamin C content in some juice samples.
Determine the effect of various factors that influence the vitamin C content in food samples.
Please work in your assigned groups and follow the suggested procedures to complete your task.

Materials:
Vitamin C indicator solution
4-50 ml beakers
1-10 ml graduated cylinder
4 medicine droppers

1 stirring rod
calculator
4 sources of vitamin C: orange juice (fresh squeezed, bottled, frozen, and canned)

Procedure:

1. Pour 15 ml of the vitamin C indicator into a 50 ml beaker.
2. Using a clean medicine dropper, add a drop of one of the orange juice samples to the indicator in the 50 ml beaker. Gently swirl the liquids to mix.
3. Continue to add orange juice, drop by drop, until the indicator changes from blue to colorless. Be sure to swirl after each drop is added.
4. Observe and count the number of drops of orange juice you needed to add to the indicator to cause it to lose all of its color. Juices low in vitamin will begin to dilute the indicator. The indicator will start to take on the color of the juice. If this occurs, indicate that no satisfactory end point was reached. Record the number of drops added in the chart on your data table.
5. Repeat step 4 two more times and calculate the average number of drops required to change the indicator.
6. Repeat the above steps for each orange juice sample being tested.
7. Record the following information on a separate sheet of paper for each type of orange juice.
   Brand Name:______________Type:______________(canned etc.)
   Serving Size:______________ounces =___________ml
   Milligrams per serving size:____________________

Data Table/Graph:

Relative Vitamin C Content of Foods
Number of Drops Needed to Change Indicator

Type of Juice	Trial 1	Trial 2	Trial 3	Average

Using the information from your data table, construct a bar graph to compare the relative amounts of vitamin C in each sample tested.

Analysis of Data:
On your own paper, answer the following questions using complete sentences:

1. Which type of orange juice was the best source of vitamin C? The worst source?
2. Before this activity, which type of orange juice did you think would be the best source of vitamin C? Why?
3. Briefly explain how you know that the different orange juices did not contain the same amount of vitamin C.

4. What are some of the factors that may have converted a good source of vitamin C to a poor one?
5. If you had to develop a label that told consumers how much vitamin C is present in the fresh orange juice you tested, how would you determine the actual vitamin C content?
6. As a result of doing this activity, suggest two questions someone might ask about vitamin C concentration in food.

Part B:
Problem:
1. Working in your assigned group, your task is to determine which juice (X or Y) contains more vitamin C. Each group member will be required to submit a separate report.

Decide on a procedure using the materials provided.
List the steps in sequence that you will use in your procedure.
Set up a table in which to record your results.
Write one or more sentences comparing the amounts of vitamin C in the two juices. Use information from your data table to support your answer.

2. Discuss with your team members what variables you might like to test and what your experiment should include. You may use juices and chemicals available in the classroom or bring your own.

Materials:
4-50 ml beakers
pH paper
unknown juice X
unknown juice Y
10 ml graduated cylinder
stirring rod
container of hydrogen peroxide
container of vitamin C indicator
iodine (Lugol's) solution
medicine droppers

Before doing the lab, submit the following information to your teacher:
The question your experiment will try to answer and your hypothesis.
A list of the materials you will need.
A description of your experimental procedure.

After conducting the experiment, submit a final report that includes the following:
Title
Initial question
Hypothesis
Methods and materials
Results including a data table and graph

A discussion and conclusion that answers the following questions

a. Does your data support your hypothesis? Use data from your experiment to support your response to this question
b. What conclusions can be made based on the results of your experiment?
c. What especially surprising information did you discover as a result of your investigation?
d. What could be done to make your procedure and/or findings more reliable?
e. As a result of your investigation, what questions do you have that need to be answered through further investigation?

Question:
Assume that everyone in the class tests the same two juices. Describe three specific things that could result in your data being very different from those other students.

Lab 7 DNA Extraction
Student Task Sheet

Background information:
DNA stores genetic information, which controls cellular growth and reproduction in all living cells and organisms. DNA is found in the nucleus of plant and animal cells. DNA can be extracted from plant and animal cells by breaking apart the nuclear membrane. Detergents are used to break apart the nuclear membrane allowing the DNA of a cell to be collected for analysis. During collection of DNA, enzyme activity must be inactivated so the DNA strands are kept intact as long, thin fibers. The collected DNA in the shape of long thin fibers allows for ease of observation and analysis.

Part A:
Your task: In part A of this investigation, you extract DNA from raw wheat germ. You manipulate materials and equipment, record observations and data, and evaluate your data. You are asked to work in your assigned groups.

Safety precautions: You are required to wear safety goggles. Be sure to handle materials and glassware carefully to avoid spillage and breakage. Do not touch the surface of the hot plate or the beaker containing hot water with your bare hands.

Materials;

2-250 ml beakers
hot plate
1.5g non-roasted (raw) wheat germ
thermometer
pH meter or pH paper
5 ml clear, colorless detergent
test tube rack
6 ml ice-cold 95% ethanol
3 g natural meat tenderizer
2-15 ml test tubes
baking soda
glass stirring rod
9 ml 4% sodium chloride solution
100 ml distilled water
10 ml and 100 ml graduated cylinders
boiling hot water bath
9 ml diphenylamine solution
3 ml standard DNA solution

Procedure (Extraction of DNA):

1. Add 100 ml of water to the 250 ml beaker and heat to 50-60^{o}C on the hot plate.
2. Add 1.5 g raw wheat germ to the warm 100 ml water in the beaker and mix until dissolved.
3. Add 5 ml detergent to the wheat germ solution, maintaining a temperature of 50-

60°C, and continue stirring for 5 minutes.

4. Add 3 g of meat tenderizer to the wheat germ/detergent solution.
5. Add 1tsp. of baking soda to 50 ml of water in the second 250 ml beaker to make a baking soda solution. Add a few drops of the baking soda solution to the wheat germ solution to bring the pH up to approximately 8. Check pH of the solution with pH paper or a pH meter.
6. Maintain the temperature of the wheat germ suspension from step 5 between 50-60°C and stir for 10 minutes.
7. Remove the wheat germ from the water bath, and place the wheat germ suspension in a clean test tube.
8. Pour 6 ml of ice-cold ethanol carefully down the inside edge of the test tube so that the ethanol layers on top of the wheat germ suspension.
9. Let the mixture stand undisturbed for 5 minutes. Observe. DNA strands appear at the interface between the ethanol-wheat germ suspension. Record your observations as directed below in the section entitled "Observations and Data Analysis".
10. Weigh a small piece of filter paper (approximately 3 X 3 cm) and label in pencil with your names. Record the weight of the filter paper as directed in the Observation and Data Analysis.
11. Use a pipette or eyedropper to draw up the DNA from the alcohol layer, and place the DNA on the filter paper. Set the filter paper aside and let it dry overnight. Reweigh the filter paper containing DNA the next day. Record your results. Calculate the yield of DNA from the wheat germ.
12. Remove some of the DNA material from the filter paper and place the DNA in a labeled test tube containing 3 ml of 4% salt solution, and add 3 ml of diphenylamine solution. You may call this test tube X.
13. Into a second test tube, place 3 ml of the standard DNA solution, and add 3 ml of diphenylamine. You may call this test tube Y.
14. To a third labeled test tube, add 3 ml of 4% salt solution and 3 ml of diphenylamine. You may call this test tube Z.
15. Place all the labeled test tubes--X,Y, and Z--in a beaker with water at 50-60°C, and record any color changes.
16. Diphenylamine reacts with the deoxyribose of the DNA to produce a blue color, which indicates the presence of DNA.

Observations and Data Analysis:
Use a separate sheet of paper to write your answers.

1. Describe the appearance of the DNA strands.
2. What can you infer about the solubility of DNA in ethanol from your observations?
3. Calculate the yield of DNA from the wheat germ.
   a. mass of filter paper ______________g
      mass of filter paper + DNA ______________g
      mass of DNA ______________g
   b. DNA yield (mass of DNA/mass of wheat germ) _______________g
4. What is the purpose of heating the wheat germ solution?
5. Why is it important to stir the wheat germ solution for 5 minutes?

6. Why is ice-cold alcohol used instead of room-temperature alcohol?
7. State whether DNA was present/absent in test tube X, Y, and Z.

Part B:

Your task: In part B, you apply the skills and concepts from Part A to a problem. Each group chooses on of the following tasks for completion in two to three class periods.

1. Plan and design an experiment to improve the extraction procedure of DNA from wheat germ without reducing the DNA yield.
2. Use different sources of DNA and apply the original procedure to determine if another source DNA produces a higher yield of DNA/gram of material compared to wheat germ.

Hypothesis or Prediction:

Use a separate piece of paper to write your answers.

A. From the information you now have regarding DNA extraction, develop a hypothesis you can test in a controlled experiment that will allow you to gather quantitative data.
B. Explain the reasoning behind your hypothesis.

Plan of Investigation:

In planning your investigation, remember that you will need to 1) design a controlled experiment based on your hypothesis, 2) list detailed steps so that someone else can follow your procedures, and 3) consider the design for the table(s) or graph(s) that is appropriate for recording your data. Consider the following questions in drawing up your plan:

What will you measure?

What materials will you need?

How will you proceed with the investigation?

How will you show your results in data tables and graphs?

Submit your experimental plan to your teacher before starting your investigation. Your evaluation will be based on the quality of your experimental plan, results, analysis of results, and conclusions.

Note. From *Science Educator's Guide to Laboratory Assessment* (pp. 109-110, 114, 117-118, 122-123, 126, 130-132, and 138-140), by R. Doran, F. Chan, P. Tamir, and C. Lenhardt, 2002, Arlington, VA: National Science Teachers Association.

Appendix D

One-Way Analysis of Variance Summary for LETeams™

Source	*df*	*SS*	*MS*	*F*	*p* value	F crit.
Between groups	3	61.89	20.63	1.91	0.137	2.75
Within groups	61	657.9	10.79			
Total	64	719.8				

Note. *F* crit. = the critical value of *F* for the alpha level of .05.