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Using hot air balloons to boost middle school students' understanding of the mole concept

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USING HOT AIR BALLOONS TO BOOST MIDDLE SCHOOL STUDENTS' UNDERSTANDING OF THE MOLE CONCEPT

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Secondary Education Option

by
Rudolph Albert Patterson
December 1997
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Approved by:

Dr. Herbert Brunkhorst, First Reader
Dr. Jim Monaghan, Second Reader
The primary purpose of this study was to investigate which of two approaches toward teaching a difficult concept is associated with a greater outcome of student success. One approach utilized a student centered and guided inquiry based lesson, while the other approach was more teacher centered and textbook directed. The concept presented was that all atoms and molecules have mass, and a large number of atoms or molecules present in a certain sample will contain more mass than a sample with fewer atoms or molecules of an identical substance; this is the foundation of the mole concept. A secondary purpose of this study was to compare attitudes of students who received the student centered instructional approach against the attitudes of the students who received the teacher centered approach. Overall, students in the experimental group (student centered, guided inquiry instruction) scored significantly higher on an end of unit exam than students in the control group (teacher centered, lecture instruction). There were no significant differences between the end of unit exam scores for higher ranking students. Students of the lower motivation, ability, and achievement of the experimental group scored significantly higher (p < .02) on the end of unit exam than students in the control group. Differences in attitudes between the experimental and the control groups were not found. This student centered, hands-on, guided inquiry activity was effective in boosting understanding of the mole concept in lower ability middle school students.
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To Mom & Dad for inspiring me
To Sylvia for supporting me
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Introduction

There are many variables that affect the outcome of student success in science education; undoubtedly one variable is the method of instruction. Some instructional strategies utilize a lecture method, others utilize an inquiry based method of instruction, as called for in the National Science Education Standards (National Research Council, 1996). Other instructional activities use a combination of effective methods. For the science educator, it is important to ascertain which methods of instruction are associated with greater student success. If the most effective methods of instruction are not utilized, then student success may not reach its potentiality. Moreover, students may have a greater likelihood of developing misconceptions about the concept, if the concept is not enhanced with suitable instructional methods.

The primary purpose of this study is to investigate which of two instructional methods used to teach a difficult concept, the mole concept, is associated with a greater outcome of student success. In this study, it is postulated that student success is related to the degree of student achievement and learning. Therefore it is supposed that, the more successful student acquires greater achievement than a less successful student. Achievement is measured using a student’s score on a final examination. It is assumed that more successful students learn and understand a concept to a higher degree than less successful students. More successful
students should be able to score higher on a final exam than less successful students. The two methods for teaching the concept are: (1) teaching using a traditional lecture/note taking & chalkboard presentation, followed by worksheets with mole-related questions, or (2) teaching by introducing the topic to students and then allowing them to solve a mole-related, hands-on, guided inquiry based problem using hot air balloons. In addition, this inquiry group is required to solve similar, but fewer, mole-related practice problems after they perform the inquiry activity.

Student success in the inquiry activity is compared to student success of the lecture/note taking & chalkboard presentation. The mole concept, an integral part of the particle theory of matter, is an abstract, difficult concept to teach. It is important that this concept be taught in a manner which ensures the highest degree of student comprehension. In this study, a guided inquiry, hot air balloon activity is proposed. The activity will allow students to concretely study molecules and their mass. Educational research studies relating to teaching students the particle model of matter, their methods and results are considered in the design of the guided inquiry activity in this study. These studies suggest that student achievement is increased by using concrete, inquiry lessons to teach the particle model of matter.

The study has two foci. These foci are to: (1) examine if instruction utilizing a guided inquiry based method of learning is associated with a greater outcome of
student success when compared to a non-inquiry based method of learning that teaches the mole concept; and (2) examine if individuals instructed in an inquiry based learning method have a significantly more positive attitude than individuals who do not receive inquiry based instruction when studying the mole concept.

The foundation of the mole concept is that all atoms and molecules have mass, and a large number of atoms or molecules present in a certain sample will contain more mass than a sample with fewer atoms or molecules of an identical substance. The mole concept is an integral part of the particle model of matter. If the student understands the mole concept, he/she may have a more complex understanding of the particle model of matter. If the mole concept is introduced effectively and early, perhaps misconceptions, about size and mass of molecules will be less likely to impair students' understanding of the particle model of matter.

Literature Review

Inquiry Based Learning:

Early in the twentieth-century, John Dewey proposed inquiry based instruction. In his book Democracy and Education (1916), Dewey suggests that the learner is naturally curious; and to satisfy this curiosity, the learner
must be encouraged to solve problems through discovery. Dewey maintains that it is the teacher’s role to guide the student in the direction which will lead the student to discover knowledge through inquiry.

Other researchers and educators agree with Dewey’s belief. It has been suggested that science needs to be taught dynamically, not as a static subject in textbooks (Yager & Penick, 1986). Science programs, dynamic in their approach, emphasize inquiry instruction (Reynolds et al., 1985). For students of science, learning is an active process. In this active process, students must be exposed to “minds-on” experiences which allow students to engage in and solve thought provoking problems. Science instruction must include inquiry learning activities in which students are able to interact with the teacher and their peers (National Research Council, 1996). The National Research Council stresses that hands-on activities are not enough. The National Research Council suggests that students begin to relate their present understanding of science with scientific knowledge contained in various resources. The method that students use to establish this relation is through inquiry learning and active group interaction (National Research Council, 1996).

Two studies investigated the effectiveness of inquiry based instruction as compared to instruction using traditional lecture/discussion method with meaningful verbal learning. Both studies found that students are more successful if they are involved in inquiry based instructional activities as opposed to verbal learning.
Findings of these studies suggest that the value of focused and specific training in scientific inquiry is important for student success (Schrenker, 1976 & Peterson, 1978).

One important task of the science teacher is to decide which methods will be most successful in teaching students. The outcome of student learning is affected by the methods used to teach students. The choices that teachers make, concerning curriculum, and learning activities used to enhance the curriculum, will influence the learning outcomes and attitudes of their students (National Research Council, 1996).

The National Science Education Standards, authored by the National Research Council, reports that teachers of science should plan an inquiry based science program for their students. The Council is eager to point out that a single approach to science teaching should not be utilized. Also it is important, the Council notes, to realize that reading can be an integral part of an effective inquiry based program.

Science instruction should require the student to make observations and collect data. These observations and data are referred to as evidence. This evidence is collected by students in inquiry science activities. The students use this evidence to understand and develop scientific models. The student uses scientific models to explain scientific phenomena (National Research Council, 1996).
Students' understanding of the atom and molecule is often misconstrued. When the misconceptions and misunderstandings are not corrected early, they may follow students into high school. Researchers emphasize that what students learn is affected by previously acquired knowledge (Krishnan & Howe, 1994). In one study, grade twelve students were found to have misconceptions about the weight change of water molecules in different phase changes of water (Griffiths & Preston, 1992). Griffiths and Preston suggest that most chemical educators generally agree that understanding atoms and molecules is fundamental in the learning of chemistry. If students have misconceptions about atoms and molecules they may never fully be capable of learning other concepts such as chemical bonding, chemical reactions, ions, and states of matter. Ensuring that students thoroughly comprehend certain concepts early, may ultimately influence the comprehension of the entire subject (Gabel & Sherwood, 1980). It is important then to enable students to learn the concepts, which are vital to a subject, correctly and early.

Students enter new learning situations with their own preconceptions. Often it is difficult for students to understand a new science concept based upon these former preconceptions (Driver, 1983). Rosalind Driver researches effective instructional methods for teaching the particle model of matter to classes of students ranging from eleven years of age to fifteen years of age. The method of
instruction in these science classrooms is to offer the student a perplexing problem. The students are allowed to perform experiments relating to the problem. From the observations and data collected in their experiments, students are encouraged to provide an answer to the problem. The students are allowed to form their own ideas. This process of learning incorporates inquiry learning activities. At the end of the activity, the teacher directs a class discussion. The students are allowed to share their ideas. The teacher then allows students to evaluate their own ideas, the ideas of other students, and the accepted scientific ideas. Driver accepts that before the students engage in the particle theory of matter lessons, each student has a certain amount of knowledge and preconceived ideas about the theory. Through inquiry activities, the students are allowed to change their ideas about the particle theory of matter.

In a related study to Driver’s, Joseph Nussbaum, utilizing the same strategies, studied pupil’s understanding of the particulate nature of gas. Eighth graders (fourteen year olds) in Israel were observed. Through a thirty minute interview procedure, Nussbaum probed the various frameworks which the pupils used to construct meaning about the behavior of gases. The majority of pupils (sixty four percent) believed that air is made up of particles, but less than thirty six percent of the pupils were able to understand that empty space resides between the particles of air. Additionally, only forty percent of the pupils understood the concept that particles possess an intrinsic motion. This
conclusion was made at the end of the study:

"The lesson learned about the tenacious nature of pupil's preconceptions should motivate us to search for more effective teaching strategies" (Nussbaum, 1985, p. 143).

Nussbaum suggests which teaching strategy should be used to make students aware of their own misconceptions about the behavior of gases. This suggestion is to expose students to observable events concerning the nature of gases. The students are then encouraged to take an explicit position about the nature of gases. The research from these studies suggests that inquiry activities are important and effective in enabling students to correctly understand the particulate nature of matter.

Findings of how hands-on, inquiry science activities affect student success and achievement

In their book Models of Teaching, Joyce and Weil (1996) indicate that students are not passive learners. Several models of teaching presented in their book, such as the scientific inquiry model and the group investigation model, allow students to be involved in active learning rather than passive learning. Additionally, researchers suggest that the success or failure which students have with instructional materials can influence students' attitudes toward science (Penick & Krajcik, 1985). Hands-on activities seem to be strongly related to higher student achievement.

Researchers involved in the development of effective lessons, designed to curtail misconceptions in students' understanding of atoms and molecules, have found some
important evidence to support hands on activities as opposed to passive learning activities. When they implemented their "hands-on" activity based lesson, after the concept was presented from the textbook, student achievement on average tripled. The lesson designers submit that this finding clearly demonstrates students' understanding of learned concepts when students are introduced to a concept and then allowed to take part in meaningful "hands-on" related activities (Schwaner, Petty, & Schwaner, 1994).

In related studies on concept learning of atoms and molecules educational researchers have found that students who were able to manipulate concrete physical molecular models had more success as opposed to those students who were only allowed to watch the teacher demonstrate the models (Gabel & Sherwood, 1980). In another related study it was found that students prefer models of atoms and molecules that depict these entities as discrete, concrete structures (Harrison & Treagust, 1996).

In a nonempirically based report, researchers argue that when science educators attempt to apply macroscopic properties to particles of matter (atoms and molecules), students will have a greater conceptual understanding of these particles (de Vos & Verdonk, 1996). They argue that five macroscopic properties of matter, which are space, time, mass, energy, and electric charge, are properties that students may apply to particles of matter in order to gain a conceptual understanding of the nature of particles.

McArthur and Wellner (1996) suggest that understanding
of spatial relationships must be obvious before students can assimilate scientific concepts and models. Also, if students are not individually acting upon three-dimensional objects for substantial periods of time, the chance for spatial structures to be built will be slim (McArthur and Wellner, 1996). These researchers report statistically significant differences in ability between students instructed using manipulatives to promote the development of logical thinking structures and students instructed without these manipulatives. In this study, the experimental group had significantly higher scores than the control group on an assessment designed to measure spatial ability. The implications of the ideas and findings reported in these studies are the basis for the presumption that hands on science activities, which allow students to make concrete observations, increase conceptual understanding.

From the results of their studies on various aspects of hands-on science activities, researchers seem to have very similar conclusions; most notably that teachers who use hands-on learning activities have students with higher achievement. Conceptual understanding of the particles comprising matter is enhanced when students are able to apply concrete, macroscopic observations to the particles. Some types of hands on learning activities, those associated with manipulating molecular models, have been shown to boost conceptual understanding in students.
Readiness of Middle School Students to Study Matter and Molecules

Educators must question at which age is it appropriate to introduce students to science concepts such as understanding molecules and the mole concept. From a study investigating middle school students' understanding of matter, molecules, and the kinetic theory of matter, researchers found that about fifty percent of middle school students are capable of understanding some important aspects of the kinetic molecular theory. These aspects include the nature of matter, the size and motion of molecules and the thermal expansions of molecules. They conclude that the ideas of the kinetic molecular theory are not beyond the intellectual reach of most sixth-grade students (Lee et al., 1993).

As mentioned earlier, students often enter new learning tasks in a context of already acquired knowledge (Krishnan & Howe, 1994, Driver, 1983). Students are more likely to be prepared for a science topic if they are introduced to concepts early (Gabel & Sherwood, 1980). In Lee's study, pertaining to middle school students' understanding of matter and molecules, over half the students did not understand molecular arrangement in different states of matter. If students do not have a sound conceptual understanding of molecules, then students may have trouble in making sense of the above mentioned topics that are introduced in textbooks (Lee et al., 1993). Lee contends that most science texts omit the issue of teaching students complex topics without
ensuring a basic understanding. Teachers attempt to teach the book driven curriculum to students, unaware of the readiness of the students for that curriculum. Lee argues that the widespread and well documented failure of our science education system is caused by teachers, who teach from a textbook curriculum, unaware of the fact that their students are unprepared for this curriculum. Lee proposes that one solution to the problem is to empower students with a broad conceptual understanding of the basic concepts important in the physical, life and earth sciences, before they reach high school. An effective way to empower students with a broad conceptual understanding of the basic concepts of science is to use dynamic teaching strategies with an emphasis on inquiry instruction and hands on activities.

Another important aspect for designers of science curriculum to consider is the simplicity of the method which is used to present an important, basic scientific concept. The extent to which the concept is presented can be scrutinized by science experts. Some methods for presentation of difficult concepts, important in science, are censured out by science experts as too simplistic, partial, and even inaccurate (de Vos & Verdonk, 1996). For example, de Vos & Verdonk explain that elementary teachers can teach their students that particles of matter are like macroscopic solid material objects, only on a much smaller scale. The elementary school student is able to accept and understand this analogy; however, this idea does not reflect the current scientific views about the particle model of matter.
Educators often allow students to draw a model to assess a student’s understanding of the arrangement of molecules in a gas. From a strictly scientific point of view, the drawing does not illustrate that exact arrangement of the particles. The model fails to explain the interactions that may be occurring between in the molecules. The model does not need to be completely accurate for the educator to assess if the student grasps the intended portion of the concept. Under certain conditions, I agree with the above reasoning. For example, if an educator attempts to evaluate a student’s understanding of one aspect of a certain concept, then it may be appropriate to use a model that attempts to explain only the isolated aspect. I believe few scientific models can explain exactly what they are designed to explain.

**Project Design/Methodology**

**Overview**

I have used two methods which allow the use of hot air balloons to teach students the mole concept. Both methods are explained later in this document. For this study, one method is preferred because it allows students to make macroscopic observations of changes in mass of a large sample of molecules. The other method is highly mathematical and does not allow the students to make concrete macroscopic observations of matter. Students can use these observations
to understand the mole concept. The proposed method applies the recommendations of de Vos & Verdonk (1996), regarding the use of macroscopic observations to teach students the particle model of matter.

If concepts are presented early, and concretely, then students' misconceptions may be prevented (Gabel & Sherwood, 1980). Lee and others (1993) suggest a readiness for middle school students to learn concepts relating to the kinetic molecular theory. I feel that the proposed method to teach the mole concept may not be too difficult for the middle school students in my classes.

Dewey (1916), Yager & Penick (1986), Reynolds et al. (1985), and the National Research Council (1996) all support hands on inquiry science activities as a method of instructing students in science. Students benefit from hands on, active, inquiry learning activities (Schrenker, 1976 & Peterson, 1978). These activities are beneficial for successful learning because students are allowed to collect and analyze data, and to interact with their teacher and peers (National Research Council, 1996). The proposed activity in this study is a guided inquiry activity. The activity will allow students to collect and analyze data, and to interact with their teacher and peers. Nussbaum (1985) suggests that in order to make students aware of their own misconceptions about the behavior of gases, students should be allowed to observe changes in gases. The method I utilized for students to find the number of moles of molecules that leave the balloon, allowed students to observe
mass, a macroscopic property of molecules. This activity allowed the middle school student to "see" or concretely visualize what was going on. Students might then be able to transfer these concrete observations to formulate their own ideas about the relationship between mass and number of molecules. This is the reason I chose the hot air balloon activity as an inquiry learning activity to examine student success in understanding molecules and the mole concept.

In order to prevent student misconceptions about atoms and molecules, Schwaner, Petty, & Schwaner (1994), suggest introducing textbook concepts to students before they are allowed to perform related hands-on activities. In this study, students were introduced to the mole concept prior to the activity.

This study is an action research project. Both the hands-on curriculum and the lecture/discussion curriculum were of my design and implementation. The specific methods are described below in the Lecture/Discussion Learning Design and Design of the Hot Air Balloon Lab.

A guided inquiry instructional activity, estimated to enhance middle school students' understanding of the mole concept, was proposed in this study. An attempt was made to measure the success of the activity, in boosting student achievement and conceptual understanding of the mole-concept. Students were able to observe a concrete loss in mass of a hot air balloon; they were then able to attribute this loss of mass to a loss of a great number of molecules forced out of the balloon, when the air inside was heated. By knowing
the quantity of the mass loss in a hot air balloon, students were then able to calculate the number of air molecules that exited the balloon when the air inside was heated.

An alternate method to be used for calculating number of moles of air that leave the balloon is to find the pressure, temperature and volume of the balloon. The Ideal Gas Law can be utilized to compare the number of molecules in a hot balloon and a balloon at room temperature. The difference between the number of moles of air in a cold balloon and number of moles of air in a hot balloon can be subtracted to find the number of moles of air that leave the balloon. The Ideal Gas Law states: \( PV = NRT \); where \( P \) is Pressure of the gas, \( V \) is the volume of the gas, \( N \) is the number of moles of gas molecules, \( R \) is a constant, and \( T \) is the temperature of the gas. This method involves an entirely abstract observation and assessment of data from the experiment. Variables such as temperature, pressure, and the \( R \) constant are not macroscopic properties of matter. I did not choose this method because it does not allow the student to "see" what is happening. Changes in temperature of the balloon are the only observable changes. It may be very difficult to relate this temperature change to a loss in number of molecules, especially for students who are being introduced to the mole concept for the first time.

The assessment instruments used to evaluate achievement were designed by me because of the difficulty in finding the specific and appropriate test items in a test bank which already had reliability and validity data. The questions
used in the pretest, the worksheet, and the post test are displayed in Appendix B, Appendix C and Appendix D respectively. The questions that I have designed in the worksheets and on the tests are all conceptual questions which require little math or no math at all. The reason I chose these types of questions is that these questions require students to think about molecules and molecular mass, without confusing students over complicated mathematical formulae. Most of the students are not capable of performing the mathematical operations in the complex mole concept problems.

The outcome of student achievement in the control group (the group that is taught using a traditional lecture/note taking & chalkboard presentation, followed by worksheets with mole-related questions), will be used to compare the achievement of the experimental group (the other group which is allowed to study the hot air balloons before they are assigned similar worksheets with mole-related questions). Both groups will be assessed by the same tests.

Preparing students to understand atoms, molecules, and the periodic table of elements

Students were taught an entire unit on matter. The objectives of the lesson are attached to the end of this document as Appendix A. All students in all classes received the same instruction for all objectives, except for the objective that deals with the mole-concept. Both the control group and the experimental group have been given the same
instruction on how to find the atomic mass of atoms of the elements on the periodic table of elements. Both groups were taught how to find the molecular mass of simple molecules. The instructional methods used for these other objectives included lecture, videos, reading from books, hands-on activities, notes, quizzes and worksheets. The instructional method for teaching the mole concept to both the control and experimental groups is explained in the following two sections.

Introductory Presentation for Both Groups

The introduction on the mole concept began with a pretest and a series of questions posed by the teacher for both groups. After the pretest, the teacher inflated a balloon with air from his lungs and tied it shut. The students were asked the question: How does the mass of the inflated balloon (including the rubber and air inside) compare to the mass of the empty balloon (rubber only)? A majority of students in both the control group and experimental group responded that the mass did not change. Another balloon was inflated with hydrogen, using hydrogen gas evolved from a chemical reaction of zinc and hydrochloric acid. The students observed the reaction as the balloon inflated. The balloon was tied shut. A string was then tied to the balloon. The balloon was allowed to float upward while the teacher held the string. The following question was posed: Which balloon has the most mass, the empty balloon (rubber only) or the balloon full of hydrogen gas
rubber & hydrogen)? A majority of students, in both the control group and experimental group, responded that the mass of the balloon filled with hydrogen had less mass than the empty balloon. They explained that the empty balloon must have more mass than the balloon full of hydrogen because the empty balloon did not float.

A discussion/demonstration about mass of molecules was led by the teacher. In this discussion/demonstration, the teacher addressed misconceptions which the students had about mass of molecules. Carbon dioxide gas was evolved from vinegar and baking soda to demonstrate the law of conservation of mass. A sample of vinegar was poured into a glass flask. A sample of baking soda was placed inside an uninflated balloon. The opening of the balloon was pulled over the top of the glass flask which contained the vinegar. The teacher was careful to not allow any of the baking soda to spill into the flask. The entire set up was weighed. The teacher then allowed the baking soda to spill in the flask by holding the balloon upright. As the baking soda fell into the vinegar, carbon dioxide gas was evolved and the balloon inflated. The entire set up was weighed. Students observed no change in mass. The balloon was removed from the flask. Carbon dioxide in the balloon was released and the balloon was replaced over the flask. The entire set up was weighed again. Students observed a mass change. When asked to explain this mass change, students explained that the mass change was due to the loss of carbon dioxide. Students were then able to realize that the molecules of hydrogen which
were used to inflate the first balloon must contain mass. The teacher explained that the reason the hydrogen balloon floats is because it is lighter than an equal amount of air in the room. Students were also informed that the reason the balloon containing carbon dioxide did not float is because that balloon is heavier than an equal amount of air in the room. The teacher asked students which gas contains the heaviest molecules. Students responded that carbon dioxide molecules must be heavier than hydrogen molecules.

Students in the control group and the experimental group were given the same lecture on how to find the number of grams of an element there are in one mole of atoms of the element. Students were told that 1 mole of a substance contains $6.02 \times 10^{23}$ atoms, or molecules or particles of the substance. Students were informed how to decipher the mass of 1 mole of atoms of an element. Students were told that the same number for the atomic mass of an element is used to express the mass, in number of grams, of 1 mole of atoms of the element. Likewise students were informed that 1 mole of molecules of a substance will be the same number, in grams, as the molecular mass of a molecule of the substance. This is the point in which the lesson diverged for both the control group and the experimental group. The experimental group received a student centered, hands on mole lesson and the control group received a teacher centered, mole lesson. The lesson design for the control group is explained in the next section entitled Lecture/Discussion Learning Design.
The lesson design for the experimental group is explained in the section entitled Design of the Hot Air Balloon Lab.

**Lecture/Discussion Learning Design**

The control group of students were encouraged to solve mole concept problems after being introduced to the mole concept via a short lecture. The teacher presented a lecture/discussion, continuing to model several examples of how to solve mole related questions. Students were required to take notes on how to solve these mole related problems. Students were then given a worksheet in which they solved three mole related questions independently. The worksheet was graded in class. Students were called up to the white board to display solutions to the questions on the worksheet. Students who answered problems incorrectly were allowed to correct their mistakes. The teacher allowed more time to explain any questions students had about the solutions to the questions. Students were given an additional ten question worksheet to complete for homework. The questions on both worksheets are presented in Appendix C.

The following day students returned with the completed ten question worksheet. The students graded their questions. As before, students were called up to present their answers to the questions on the white board. Any students still having trouble with the questions were allowed to correct their mistakes. The teacher led a final discussion in which students were encouraged to formulate new questions, similar to their worksheet questions, and arrive at a solution to the
questions. The mole concept lesson was completed in three days. The students were evaluated by means of a post test on the fourth day.

**Design of the Hot Air Balloon Lab**

Students were previously introduced to the mole concept through a short lecture/demonstration. This same lecture was used in the control group. The details of the lecture are discussed in the section above entitled *Introductory Presentation for both groups.* Students were encouraged to solve a problem concerning how many moles of air leave a hot air balloon in order to cause the hot air balloon to become buoyant. Students were informed that 1 mole of air weighs 28 grams. A class discussion was conducted in which students were allowed to brainstorm ideas of how to figure out the weight of all the molecules that leave the balloon. Students were encouraged, through the discussion, to make the inference that if weights of known mass are attached to the bottom of the balloon, and these weights cause the balloon to hover at the same level, neither rising or falling, over a flame of a camping stove, then the amount of mass that the weights contain, included with the weight of the balloon material, is equivalent to the amount of mass of air molecules that leave the balloon.

The room was kept at the same temperature throughout the class period. This allowed the air density to remain constant so that the only variable affecting buoyancy of the balloon was the mass attached to the bottom of the balloon. Students were given thin, light Hefty trash bags for hot air
balloons; the bags all had the same volume.

Students were asked to make inferences about the number of moles of air that leave the balloon. Their inference was to be to the nearest one hundredth of a mole. Students were informed to multiply this number by 28 to calculate the equivalent mass in grams of air molecules that leave the balloon. Students worked in groups of three to four. Each group was allowed to make several inferences at the amount of moles and the mass of molecules that leave the balloon; however, they only got one opportunity to test and validate one inference. Each group in the classroom observed the results of the launches of the other groups. Groups who had not launched their balloons were allowed make new inferences after they discovered the outcome of the launch of other groups performing the experiment first. Through cooperative and collaborative learning, the entire classroom of students engaged in a hands on activity, that utilized a guided inquiry activity, to discover the mass of air molecules and the number of moles of air that leave the balloon. As closure to the lesson, I used the white board to demonstrate the process of calculating the number of molecules that leave the balloon. I simply multiplied the final most accurate guess of the number of moles of air molecules that exit the balloon by Avogadro’s number. I calculated the two closest guesses on the number of moles of air that leave the balloon. Students were then able to compare actual differences in terms of numbers of molecules, masses, and moles of molecules. I did not require students to engage in these
more complex mathematical calculations used to determine number of moles or mass.

The students did have an opportunity to measure and observe mass changes in molecules they could not see. From these observations students may have been able to infer the quantity of molecules that leave the balloon. The closure demonstration allowed me to help students confirm or refute their inferences. This activity was designed to enable students to assimilate a basic understanding of the mole concept. After the completion of the activity, students should have been able to associate mass of molecules with number of molecules. When the balloon became hot and lost molecules, it also lost mass. This activity served as an instructional method which attempted to prevent students from formulating certain misconceptions about molecules.

At the end of the hot air balloon activity, the students were given a worksheet with three mole related questions. This worksheet is presented on the top of Appendix B. The students returned this worksheet the following day. The worksheet was graded in class. Students were allowed to correct any problems which they got wrong. Finally the students were encouraged to formulate and solve their own mole related questions, similar to those on the worksheet. The solutions to these questions were displayed on the white board by the students. The lesson was presented in three days. On the fourth day, the students were evaluated using the identical test that was administered to the control group.
Methodology

Three science classes out of six science classes that I taught were randomly chosen to perform in the control group. The three other classes were used as the experimental group. The class samples were randomly chosen using the random function in the Claris Works spreadsheet. Since there is a seven period day at my school, I used the number 7 in the random function. I performed this random function three times. Each result was recorded. The results from these three random number generations were 1, 3, and 5. I used class periods one, three, and five for my experimental groups. Periods four, six, and seven were chosen as the control groups. I did not teach during period two because it was my conference period. A total of eighty-five students were enrolled in the three experimental group classes. In the control group, a total of seventy-seven students were enrolled. Students who were English language deficient, or students who were not able to read at or above a fifth grade reading level were not used in the study. The total number of subjects that qualified for the study were fifty-nine for the control group, and fifty-nine for the experimental group. Because the student subjects used in this study were limited to only the students in my science classes, this sample did not necessarily reflect a random population sample. Students in all classes were in the same age group (twelve years of age to thirteen years of age); there were no students included in the study who had a chronological age less than or greater than the seventh grade level.
Students in each sample were subdivided into two achievement groups. The academic grade point averages for each subject included in the study were obtained and arranged in a frequency distribution. The grade point averages were then converted into percentile ranks and students were divided up into equal achievement/ability groups based upon grade point average status. The fiftieth percentile matched up with a 3.0 G.P.A. Students with a G.P.A. above 3.0 were placed in the high ranking achievement/ability groups. Students with a G.P.A. below 3.0 were placed in the low ranking achievement/ability groups. Appendix F, Table 1 shows these groups and their grade point averages.

The readability of the assessment instrument, used to measure achievement and understanding of the mole concept, was determined to be at the fifth grade reading level, using the Fry readability graph. The Fry readability calculation method compares numbers of syllables in a passage to the number of words in the passage. The grade level is then interpolated from a readability graph (Vacca, 1981).

Students total reading scores were determined using the California Test of Basic Skills results for fall 1996. Any student who performed at a 5th grade total reading level or above was included in the sample. All students reading lower than that level were excluded from the study; however, they were still allowed to engage in the lesson. It is difficult to determine the effect of losing these students from the study. Some of these disqualified students were high achievers and highly motivated; however, they were not able
to read at the level of the post test. The scores that these students obtained were excluded from the results. Other disqualified students were low grade level readers, fairly unmotivated, underachievers. Data from these students was excluded in the final results. With such a large number of excluded students the sample size of both the control group and the experimental group was considered to be a statistically large enough sample for quantitative.

All students in all classes were given the same pretest. This pretest consisted of ten multiple choice questions relating to matter, atoms and molecules; five of the ten questions related to the mole concept. A copy of these test questions is found in Appendix B. Prior to instruction, a measure of each student’s understanding was estimated about the mole concept. This estimated measurement was based upon the raw score of the five mole-related concept questions each student answered correctly. The average results for each group is reported in Appendix F, Table 2. T-tests between two independent samples were used to test significance. This procedure was performed to attempt to show that neither group had a greater understanding of the mole concept before instruction.

At the end of the unit, each student was given the same post test, which consisted of a ten true/false, seventeen multiple-choice and five matching questions. Only four of the true/false questions and eleven of the multiple choice questions were used to obtain an estimate for understanding of the mole concept. All these test questions were used
because correct responses to them are based upon conceptual reasoning. It seems unlikely that a student could answer all questions by random guessing. Also a student relying on memorized facts, without relying on conceptual reasoning, may not be able to generate as many correct responses as a student who uses conceptual reasoning. These test questions are displayed in Appendix D.

After the post test, each student was given a seven question survey in which they rated their motivation and enjoyment of the instructional method used in learning the mole concept. The questions on the survey required one of four responses. The responses were: strongly disagree, disagree, agree, strongly agree. A number from 1 to 4 was assigned to these responses. Strongly disagree was assigned the value of 1 and strongly agree was assigned the value of 4. A sample of the identical survey that was given to all students is found in Appendix E. Total mean scores for individuals were equated with a measurement for attitude. A mean score of seven was the most negative attitude and a mean score of twenty eight was the most positive attitude. Appendix F, Table 4 shows the mean score results for males and females in the control and experimental groups.

The experimental groups’ post test mean scores were compared to the control groups’ post test mean scores. T-tests between two independent means were used to make statistical comparisons. In addition, both the control and the experimental groups were subdivided into two categories based upon ability and achievement. Mean score results of
both the high ability/achievement groups in the control group and the experimental group were compared with each other. Similarly, the mean score results of both the low ability/achievement groups in the control group and the experimental group were compared with each other. Appendix F, Table 3 displays the results of the mean score comparisons between the groups.

Results

Using the t-tests between two independent means, no significant differences were found between the pretest scores of the experimental group and the pretest scores of the control group students. T-tests between two independent means were conducted to compare post test mean score results of the control groups and the experimental groups. The significance of the differences between the mean scores were revealed and the probability level for each significant difference was indicated. In every case, the mean scores of the experimental group were higher than the mean scores of the control group. Significant differences beyond the $P=.02$ level were found between the total mean scores of the experimental group and the total mean scores of the control group. It is interesting to note that the only ability/achievement groups to retain significant differences were the lower ability/achievement level groups.

Using a complex Chi-square statistical test, attitudes about the enjoyment of learning moles were compared. Attitudes of boys in the experimental group did not vary
significantly with attitudes of boys in the control group. Also, girls' attitudes in the experimental group did not vary significantly with girls' attitudes in the control group. Appendix F, Table 4 shows these attitude comparisons.

Conclusion

Discussion

This study was an action research study. There are some limitations to the study. The tests which attempted to measure students' preliminary understanding of the mole concept, achievement and understanding after the unit was taught, and attitudes and motivation did not have a measure of validity and reliability. Since this study was conducted using tests in which validity and reliability statistics were unknown, then conclusions about how the findings relate to the entire population could not be made.

I was the only researcher teaching students the concept and collecting data. This can be viewed as a means of controlling one important variable, which is inconsistency among several teachers' methods. However, the beneficial outcome of having more than one researcher is that several researchers who use the same methods, decrease the chance of experimental error from occurring. Also more profound generalizations can be made from consistent data of several researchers.
A bias that may have had an impact on the outcome of the results is the Hawthorne effect. This effect occurs when people perceive they are being given special attention; as a reaction to their perception, their behavior changes. Students in the control group inquired about not getting to do the hot air balloon lab. Students in the experimental group who did get to perform the hot air balloon lab may have perceived they were special. I assured students that I would eventually let all classes do the lab; however the control group did not get to do the lab until after they took the post test. My explanation to the students as to why I did not allow all classes to participate in the hot air balloon lab during the same day is that I was too exhausted to teach six big labs like that in one day. After the study was completed, I informed all classes of the study; I asked them if they perceived that I was performing a study on them. The answer of all classes was consistently no. This persuades me to conclude that the impact of the Hawthorne effect was minimal.

Significance of Results/Summary

The results of the study have implications for science teachers and curriculum administrators in the school district in which I teach. Because this in an action research project, its findings cannot necessarily represent the entire population of seventh grade students. The findings are limited to the classes in which I teach. Because there were no significant differences between the higher
ability/achievement groups, this may suggest that students of high ability and achievement learn and become successful with either a hands on learning activity or a lecture/discussion presentation. There were significant differences on the final assessment between lower ability/achievement students of the experimental group and lower ability/achievement students of the control groups. The students who are below average in ability and achievement may benefit from hands on learning activities which attempt to enhance student understanding of difficult concepts. Success for below average students seems to be influenced by hands on learning activities as opposed to lecture/discussion instruction. Lecture and discussion presentations seem to lack effectiveness for these learners. The reason may be due to the fact that activities which allow the student to make macroscopic observations serve to make the learning experience less abstract. These findings may provide credibility to the effectiveness of using hands on activities to facilitate and teach difficult concepts such as the mole concept. The findings also seem to support findings from previous studies which conclude that hands on activities increase students’ ability to understand difficult concepts (Schwaner, Petty, & Schwaner, 1994).

Although research indicates that inquiry hands on activities boost student attitudes, in my classroom attitudes of students were not significantly higher for the experimental group when compared to the control group. Attitudes could have been influenced by the time of the year.
the study was conducted. This study was conducted during the last unit of the school year. Students seemed to be less interested toward the end of the school year. Additionally, it is hard to determine the effect that this timing may have had on the overall learning of the unit.

In this modern age of computers, science teachers, and other teachers, are equipped with new and effective ways to deliver presentations to their classes. This technology is valuable; however, science teachers should not forget about the effectiveness of dynamic hands on learning activities to facilitate conceptual understanding among their students. In science there should be no substitution for effective hands on, inquiry learning activities.

The scope of this study is confined to studying the effects of a hands on activity in affecting students’ understanding of the mole concept in three seventh grade classrooms. Despite the limitations of the study, its results may provide valuable information for further studies on the topic. Suggestions for further study include, assessment questions be developed and utilized which have established validity, and which have a reliability coefficient. Also the study should be carried out nationally using a large number of teachers teaching the lesson. The study should be conducted mid-year when the students are not anxious about the start of school, nor excited and anticipating the end of the school year.
Appendix A: Lesson Plans on Matter and Molecules

Objectives:
1. Students will list three states of matter and describe each state.

2. Students will be able to state the smallest particles of matter (atoms & molecules) and describe them in terms of mass and their size in relation to the organization of the universe.

3. Students will be able to state three sub-atomic particles and describe each in terms of mass and charge.

4. Students will understand that the more molecules of any element that are present in a given sample then the greater the mass of the sample will be. Students will understand the mole concept in terms of mass and number of particles.

5. Students will be able to use the periodic table of elements to find information about atoms of the elements.

6. Students will be able to state the law of conservation of matter.

7. Students will be able to state the law of conservation of mass.
Appendix B: Pretest on Matter, Atoms, and Molecules

The following 5 questions were taken from a pretest given to students prior to studying a unit on matter, atoms, & molecules. Each question relates to the mole concept; students' raw test scores for my study were based upon the number of correct responses from these 5 questions.

Multiple Choice: Read each question below and choose the letter of the best answer.

1. If a balloon was filled with molecules of air and tied shut, what would happen to its mass and weight?
   a) Both mass & weight of the balloon will be the same as the balloon when it is empty.
   b) Both mass & weight of the balloon will be less than the balloon when it is empty.
   c) Both mass & weight of the balloon will be greater than the balloon when it is empty.
   d) None of the answers above is correct.

4. If a small piece of metal was placed in a container of strong acid, what would happen to the metal?
   a) The metal will be dissolved into nothing and will be gone forever.
   b) The metal will combine with the acid to make a new substance.
   c) The metal will change into acid.
   d) The metal will melt.
   Note: This question was not used in the raw test score; it is included for reference to question 5 below.

5. In question number 4 above, what would happen to the total mass & weight of the container, and its contents of acid and the metal, if you sealed the container shut so that nothing could enter or escape?
   a) The mass & weight of the container would not change.
   b) The mass & weight of the container would get lighter.
   c) The mass & weight of the container would get heavier.
   d) The above answers are all incorrect.

8. If a balloon was filled with helium; what would happen to its mass & weight?
   a) The balloon full of helium would have less mass & weight than an empty balloon.
   b) The mass of the balloon would not change.
   c) The balloon full of helium would have more mass & weight than an empty balloon.
   d) Both b & c are correct.
9. If two balloons were both filled with air; however one balloon had less air inside than the other, how would the masses and weights of each balloon compare?
   a) Air will have no effect on the mass and weights of the balloons; they will be the same.
   b) The balloon with less air would have less mass & weight.
   c) The balloon with more air would have less mass & weight.
   d) both a and c are correct.

10. What happens to the mass & weight of the Goodyear blimp when it is filled with more and more helium?
   a) It gets lighter and has less mass with greater amount of helium used to fill it up.
   b) it gets heavier and has more mass with greater amounts of helium used to fill it up.
   c) its mass and weight do not change no matter how much helium is used to fill it up.
   d) none of the above answers are correct.
Appendix C: Worksheet Questions

Worksheet I. Questions Both groups received these questions.

1. What is the mass of 1 mole of gold atoms?
2. How much would 2 moles of copper atoms weigh?
3. Figure the mass of 1 mole of water molecules (H₂O).

Worksheet II. Questions Only the control group received these questions.

1. Define a mole.
2. How would the mass of a balloon change if it was inflated with 1 mole of hydrogen (H₂) molecules?
3. How many moles of molecules are there in 12.011 grams of carbon?
4. Which contains more atoms; a mole of carbon atoms or a mole of oxygen atoms?
5. Which is more massive; a mole of lithium atoms or a mole of boron atoms?
6. Which balloon is more massive; a balloon filled with 1 mole helium or a balloon filled with 1 mole of oxygen?
7. Circle the Molecule which contains more mass? H₂O, CaCO₃, HCl?
8. If you had a silver ring with 1 mole of silver atoms and a gold ring with 1 mole of gold atoms which ring would be more massive?
9. What is the difference in masses of the above two rings?
10. If a helium balloon lost 1 mole of helium, and started to sink would its mass get larger or smaller or stay the same? If the mass does change, by how much would it change?
Appendix D: Test on Atoms, Matter, and Molecules

The following 15 questions were taken from an end of unit test on atoms, molecules, and matter. Each question relates to the mole concept; students’ raw test scores for my study were based upon the number of correct responses from these 15 questions.

You may need to refer to the Periodic Table of Elements to answer some questions. You will find a copy of the Periodic Table of Elements on the last sheet of the test.

**T-F:** Read each statement carefully; decide if the statement is true or false. Darken in ‘A’ on your scantron if the statement is true and ‘B’ if it is false.

1. ___ A molecule by itself does have a tiny amount of mass.
2. ___ It is possible to find the number of molecules present in a substance if you know the mass of that substance.
5. ___ If you had 1 mole of gold atoms and 1 mole of silver atoms, this means you would have the same number of atoms of gold as compared to silver.
9. ___ 1 mole of hydrogen is lighter than 1 mole of helium.

**Multiple Choice:** Read each question or statement and choose the letter of the choice that best answers the question or completes the statement; darken in that letter on the corresponding number of your scantron sheet.

11. Which molecule has exactly twice the mass as a molecule of CH₄ (methane)?
   A) H₂O  B) C₆H₁₂O₆  C) O₂  D) SiO₂  E) HCl

15. What is the mass of exactly 1 mole of gold atoms?
   A) 118  B) 79  C) 10  D) 197  E) 4

16. If you had an equal number of sodium atoms and argon atoms, how would their masses compare?
   A) Since there is an equal number of atoms there will be an equal mass.
   B) Sodium will have less mass than argon.
   C) Argon will have more mass than sodium.
   D) Sodium will have more mass than argon.
   E) both B & C are correct.
17. If a balloon was filled with molecules of air and tied shut, what would happen to its mass and weight?
A) Both mass & weight of the balloon will be the same as the balloon when it is empty.
B) Both mass & weight of the balloon will be less than the balloon when it is empty.
C) Both mass & weight of the balloon will be more than the balloon when it is empty.
D) None of the answers above is correct.

19. $6.02 \times 10^{23}$ number of things is called a ____________.
A) mole
B) gross
C) kilo
D) dozen
E) it is not possible to count this number of things

21. Which would have more mass?
A) a balloon filled with 1 mole of hydrogen
B) a balloon filled with 1 mole of helium
C) a hot air balloon filled with 1 mole of air molecules
D) All of them would have an equal mass.

22. What would happen to the mass of a glass of water if you took out 1 mole of water molecules?
A) It would gain 18 grams of mass.
B) It would lose 18 grams of mass.
C) That would be so few molecules that it would be difficult to say.
D) It would stay the same.

23. What happens to the mass of the Goodyear blimp when it is filled with more and more helium?
A) It has less mass with greater amounts of helium used to fill it up.
B) It has more mass with greater amounts of helium used to fill it up.
C) Its mass does not change no matter how much helium is used to fill it up because, helium has no mass.

24. If two balloons were both filled with air; however one balloon had less air inside than the other, how will the masses and weights of each balloon compare?
A) Both balloons will have the same mass; air will not change the mass of the balloon.
B) The balloon with less air will have less mass.
C) The balloon with more air will have less mass.
26. What is the mass of $6.02 \times 10^{23}$ molecules of NH₄?
A) 18 grams    B) 22 grams    C) 1 pound    D) 5 grams
E) both B & C are correct

27. Which of the following has the same mass as $6.02 \times 10^{23}$ molecules of NH₄?
A) $6.02 \times 10^{23}$ molecules of HCl
B) 1 mole of H₂O
C) $6.02 \times 10^{23}$ atoms of gold
D) 1 mole of SiO₂
Appendix E: Attitudes Survey

Survey to measure students' attitudes and enjoyment of the teaching method which was utilized to enable them to understand the mole concept.

Check one that applies to you: ___ male ___ female

Read each statement and rate it according to the feelings you have. Circle the choice that best describes your feelings about each topic.

1. I enjoyed learning about moles.
   strongly disagree disagree agree strongly agree

2. I enjoyed the teaching method that was used to help me understand the mole concept.
   strongly disagree disagree agree strongly agree

3. I have a good attitude about studying moles because of the method that was used to teach me the concept of moles.
   strongly disagree disagree agree strongly agree

4. I feel successful in learning the mole concept in the way it was taught to me.
   strongly disagree disagree agree strongly agree

5. I am interested in studying about atoms, molecules and moles in the future; especially when I get to high school.
   strongly disagree disagree agree strongly agree

6. Learning about the concept of moles is interesting.
   strongly disagree disagree agree strongly agree

7. I enjoyed the challenge of solving the problems associated with moles.
   strongly disagree disagree agree strongly agree
### Appendix F: Data Tables

#### TABLE 1: ABILITY/ACHIEVEMENT GROUPS BASED UPON GRADE POINT AVERAGE

<table>
<thead>
<tr>
<th>High Group: G.P.A. 4.0 to 3.0</th>
<th>Low Group: G.P.A. 2.9 to 0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N) experimental group = 31</td>
<td>(N) experimental group = 28</td>
</tr>
<tr>
<td>(N) control group = 31</td>
<td>(N) control group = 28</td>
</tr>
</tbody>
</table>

#### TABLE 2: MEAN PRETEST SCORES BASED ON 5 QUESTIONS

<table>
<thead>
<tr>
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<th>Total Group Mean</th>
<th>High Group Mean</th>
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<tr>
<td>Control Group</td>
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<td>1.46</td>
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</table>

#### TABLE 3: MEAN POST TEST SCORES BASED ON 15 QUESTIONS

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<th>Total Group Mean</th>
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<tr>
<td>Control Group</td>
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<td>8.42</td>
<td>6.07</td>
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</table>

\[ t \text{ value} = 2.60 \quad t \text{ value} = 1.50 \quad t \text{ value} = 2.68 \]
### TABLE 4: DIFFERENCES IN ATTITUDES AMONG THE CONTROL & EXPERIMENTAL GROUPS

<table>
<thead>
<tr>
<th></th>
<th>Mean Score 1 to 7</th>
<th>Mean Score 8 to 14</th>
<th>Mean Score 15 to 21</th>
<th>Mean Score 22 to 28</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Group Males</td>
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<td>7</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td><strong>Control</strong></td>
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<tr>
<td>Group Males</td>
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<td>26</td>
<td>6</td>
</tr>
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</table>

Chi-Square statistic .39, no relationship between attitudes of boys in experimental group and attitudes of boys in the control group.

<table>
<thead>
<tr>
<th></th>
<th>Mean Score 1 to 7</th>
<th>Mean Score 8 to 14</th>
<th>Mean Score 15 to 21</th>
<th>Mean Score 22 to 28</th>
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<tbody>
<tr>
<td><strong>Experimental</strong></td>
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<tr>
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<td>1</td>
</tr>
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<td><strong>Control</strong></td>
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<tr>
<td>Group Females</td>
<td>1</td>
<td>3</td>
<td>14</td>
<td>3</td>
</tr>
</tbody>
</table>

Chi-Square statistic 1.81, no relationship between attitudes of girls in experimental group and attitudes of girls in control group.

*A mean score of 1 indicates the most negative attitude and a mean score of 28 indicates the most positive attitude.*
References


