The Effectiveness of Inquiry-Based Learning Laboratory Experiments on Science Education Students' General Science Laboratory Attitudes and Achievement

فاعلية التعلم الاستقصائي في التجارب العلمية على تحصيل الطلبة وسلوكهم

by

HANA OSAMA ALI ABUHEJLEH

Dissertation submitted in fulfilment

of the requirements for the degree of

MASTER OF EDUCATION

at

The British University in Dubai

October 2018

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Abstract

The research paper is an analysis of the effectiveness of using inquiry based learning laboratory experiments on science education student's general science laboratory attitudes as well as achievements. As such, the research question addressed in this analysis is to discern the impact of the inquiry based learning model in determining the performance as well as achievements students in such an academic setting. Therefore, the paper will focus on analyzing all the concepts of learning evident from the inquiry based form of learning, and applying these concepts to the learning outcomes of students. The results prove that the inquiry based model of learning is effective in promoting the achievement of students in general science laboratory, as well as transforming their attitudes positively towards the subject.

Key words: Inquiry-based learning, scientific method

الملخص

يعد الاستقصاء من الناحية التربوية نظرة للتعلم تتضمن عملية استكشاف العالم الطبيعي، وتقوم على طرح أسئلة، والقيام بتحريات من أجل الوصول إلى فهم جديد، وهو يساعد الطلبة على أن يكونوا علماء أو مستكشفين بأنفسهم، كما يمكنهم من امتلاك معرفة يمكن أن يطبقوها في حياتهم اليومية، ويوفر لهم فرصا لينخرطوا في تعلم نشط قائم على أسئلتهم هم. ففي الاستقصاء يسلك الطالب سلوك العالم الصغيرفي بحثه وتوصله للنتائج، كأن يحدد المشكلة، ويكوّن الفرضيات، ويجمع المعلومات، ويلاحظ، ويقيس، ويختبر، ويصمم التجربة، ويتوصل إلى النتائج.

كما تؤكد على استمرارية التعلم الذاتي، وبناء المتعلم من حيث ثقته واعتماده على نفسه، وشعوره بالانجاز، واحترامه لذاته الابداعية.

الكلمات والعبارات الرئيسية: التعلم القائم على الاستقصاء ، المنهج العلمي.

Dedication

This dissertation is dedicated to my wonderful and greatest mother “Fatima”, my supportive father “Osama”, sisters and brothers who have always loved me unconditionally and always been a constant source of support and encouragement during the challenges of my whole college life.

I also dedicate this work to my precious friend “Rihan”, thank you for your understanding and encouragement in many, many moments of crisis. A special feeling of gratitude is to my twin sister’s kids, Lily Leen, Omar and Judy for always making me happy and beloved.

Acknowledgements

I would like to sincerely acknowledge and thank my dissertation supervisor, Prof. Sufian Forawi, for his patient, guidance and support throughout this study.

I would also like to thank my principle, assistant head, colleagues and students who were supportive and helpful, I do really appreciate it.

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Chapter One: Introduction

1.0. Introduction

There are many different forms of learning used in various teaching and education centers such as problem based learning and inquiry based learning. The choice of a learning platform is dependent on the learners as well as the teachers, in addition to the desired outcome from the learners (Abdi, 2014, p.37). The following research study focuses on the concept of inquiry based learning as one of the best learning platforms adopted across major teaching and learning situations. In this regard, the purpose of this research study is to determine the effectiveness of inquiry based learning laboratory experiments on science education student's general science laboratory attitudes as well as achievements (Almuntasheri, Gillies & Wright, 2016, p.16). Conversely, the findings of the research study will be instrumental in determining the impact of learning methods on the attitudes and performance of students in a science class, thereby guiding concerned stakeholders on the best course of action that will guarantee achievement of the most impressive outcome from the learners.

1.1. Inquiry Based Learning

Inquiry based learning refers to a form of active learning involving the use of questions or inquiries in order to facilitate the teaching and learning processes respectively (Avsec & Kocijancic, 2014, p.1436). In this case, the teacher gives the learners an opportunity to ask some questions regarding the topic of discussion or topic under study before the start of the learning session. Similarly, the teacher can also ask the students specific questions regarding the lesson or topic of discussion. The presentation of questions before the learning session opens the minds of the learners by planting the seed of curiosity in them as they work towards obtaining the right answers to the questions asked, which will probably be delivered in the course of learning (Beck, Butler & da Silva, 2014, p.444). In this regard, it is appropriate to consider this schema of asking questions before the learning session as a precedent for the learning objectives for the students in a particular topic or subject.

Consequently, as an active form of learning, inquiry based learning allows for the presentation of scenarios, problems as well as questions from both the learners and the students as opposed to the straight forward presentation of established facts about the study topic (Brown, 2016, p.304). As such, this approach brings about some fun in the learning process, especially considering the fact that it shies away from portraying the learning process as merely a smooth pathway to the dissemination of knowledge (Buckner & Kim, 2014, p.99). Nonetheless, it is imperative to note that in order for inquiry based learning to be effective in achieving the desired results, the students must always adopt it with the assistance of a facilitator, who in this case can be a supervisor, a teacher, or a professor.

It is imperative to note that the inquiry approach to learning focuses more on the utilization as well as integrating the learning content as the best means in the quest to develop sharp information-processing and problem-solving skills (Capps & Crawford, 2013, p.1947). In addition, the inquiry approach pays more concern to the learner, in this case the student, whereby the teacher or the lecturer simply acts as a facilitator to the learning process. According to Cheung et al., (2017, p.58), the inquiry based learning approach significantly improves the involvement of students in the learning process, especially with regard to the construction of knowledge through active involvement in the learning process.

The reason why inquiry based learning is widely accepted as the best model of learning in most learning institutions as well as educational settings is largely attributable to the fact that the inquiry based learning uses the questions, inquiries, curiosities as well as interests of the students in a subject or a topic to drive learning as opposed to concentrating on the presentation of a set of facts (Chiang, et al., 2017, p.1098). As such, the level of student involvement in this form of learning transforms the perception of students towards learning, especially with regard to their attitudes and performance, as the students begin considering the topic or the subject as relevant. Chiang, Yang & Hwang (2014, p.352) argue that the learning approach also encourages students to develop their personal agencies as learners, in addition to developing crucial skills in critical thinking.

Inquiry based learning is also widely accepted because it promotes active participation of students in the learning process through presentations of inquiries regarding the subject under discussion (Chiang, Yang & Hwang, 2014, p.97). Therefore, through the development of questions before the start of the learning process and the investigation of possible solutions to the questions, the students become more alert in the learning process, not to mention become more enlightened in the subject or topic of study. Contant, et al. (2017, p.11) argue that this is also largely attributable to the fact that the inquiry based learning platform adopts a hands-on approach to the learning process, which in turn further enhances the learning outcomes and attitudes of the learners. For instance, a teacher can lead the students in conducting an investigation as the students follow along closely as would be the case in a recipe (Clark & Foster, 2017, p.260). The inquiry based learning promotes thinking and brainstorming of answers among students through the curiosity raised from the questioning of every bit of the learning process as it enables students to come up with questions to investigate.

Consequently, in applying the inquiry based learning approach in science, students get an opportunity to explore possible solutions, develop explanations for the phenomena under investigation, elaborate on concepts and processes, as well as evaluate or assess their understandings in the light of available evidence (Crawford, et al., 2014, p.193). In this regard, the following research study will determine the extent of effectiveness in the learning process whereby science education students adopt the inquiry based learning approach in their laboratory experiments. Furthermore, this will also have a significant impact on the general science laboratory attitudes as well as achievements of the students (Donnelly, Linn & Ludvigsen, 2014, p.572). As such, the findings of this research study will be instrumental in informing the choice of the best active learning platform for science education students.

1.2. Background of the Research Study

1.2.1. Study of Science

The study of science is all about discovery of new things and ideas that would improve the living standards of human beings (Ellis & Bliuc, 2016, p.970). In fact, science has been the main source of the modern day solutions to common problems and challenges that people face on a day to day basis. For instance, science has been the main source of the medical solutions currently used in treating and preventing the spread and infection of people from diseases thereby saving lives. In addition, science has also played a critical role in the modern day technological advancement which goes a long way in improving the standards of life as well as introducing comforts and pleasures in life (Friesen & Scott, 2013, p.18). In this regard, there is needed to make the learning process of science not only interesting but also fruitful in order to increase the number of potential scientists in the choices made by students to study science while in high school and college.

Research has proven that most students shy away from pursuing science because of their wrong predetermined presumptions relating to the scientific topic or subject (Goossen, et al., 2016, p.18). Some students consider physics as a difficult subject, while others fear chemistry because of the chemical reactions that may be fatal in the event they mix wrong chemicals during a laboratory session. Nonetheless, it is clear that most of these predetermined presumptions regarding the study of science as being difficult is largely attributable to the learning processes applied by tutors in the study of science (Greenwald & Quitadamo, 2014, p.100). Of specific concern is the laboratory part of these science classes which further bloat the fear among most of the potential learners, thereby making them to shy away from studying sciences.

1.2.2. Effective Models of Learning

In this regard, education stakeholders as well as those in the science fields considered it imperative to introduce an effective model of learning in order to transform the students' attitudes from negative to positive in order to increase the number of students enrolling to study science, as well as improving the performance of these students who enroll to study science (Gutierez, 2015, p. 118). One of the best approaches considered as most suitable in promoting the development of learning attitudes and improving the achievement of students in science classes was considered to be the platform of learning. In previous cases, research proved that most students failed their science classes because of the adoption of teacher centered learning approach as opposed to the student centered learning approaches in science classes (Hadjichambis, et al., 2016, p.261). Consequently, it was proposed that the teaching and learning of science should adopt a student centered approach, and preferably an active learning approach in order to boost the outcome of the students.

1.2.3. Inquiry Based Instruction

As such, the inquiry based learning approach is considered as one of the best learning approaches in this case as it is not only student centered, but it also ensures that the learners participate actively in the learning process by arousing their curiosity about the new topic or science subject before they commence learning through submission of questions and other forms of inquiries before embarking on the learning process (Haq, 2017, p.11). Therefore, it is believed that the curiosity of the students to get the right answers to their questions and also getting these answers quickly will not only improve their attentiveness and participation in the class, but will also improve their learning speeds, considering the fact that most of them will study ahead of their facilitators in a quest to quench their undying thirst for answers (Harrison & Parks, 2017, p.117).

Inquiry based learning takes the emphasis away from the teacher and places it onto the students (Harrison et al., 2017, p. 91). In doing so, the students take ownership of the learning process and have a more robust vested interest in their education. The four steps of inquiry based learning each highlight the way in which the students are given agency in the learning process (Ergulec et al., 2016, p. 2610). The first step is for students to develop their own questions (Harrison et al., 2017, p. 92). The research indicates that learners are more willing to do the work required to answer questions that they, themselves, formulated. Ideally, the question should use a constructed response and require learners to engage in further inquiry either through research or experiment (Swan & Sleeter, 2017, p. 1-2).

The second step of inquiry based learning is to use the time in class to answer the question. This step is key because it allows students to have access to the resources they need to find the answers to their questions. Resources available in the classroom include the teacher who is a subject-area expert (Montrieus et al., 2017, p. 3948; Swan & Sleeter, 2017, p. 3). These resources are likely not available outside of the classroom, so the work must be conducted within the right setting.

The third step is to have students present to the class what they have learned. It is best to have each student or team of students present an artifact that is culminating (Swan & Sleeter, 2017, p. 2). The process of sharing information discovered serves both the student or students who found the answer through inquiry based learning and the rest of the students in the class. By sharing or teaching their findings to their peers, students learn the information better and get the opportunity to practice communicating their findings (Harrison et al., 2017, p. 99-100). The end result is highly-developed language, research, critical thinking, and presentation skills (Ergulec et al. 2016, p. 2612).

The fourth step for effective inquiry based is to encourage students to reflect on what they did and identify what worked well and the areas that are in need of improvement. Reflection is proven to be an excellent means of learning and a way for students to develop key critical thinking skills (Taylor, 2017, p.59). Inquiry based learning is student-centric, so it is appropriate to combine reflective activities with it. In doing so, insights can be obtained which have been shown to promote mental development and improve students' abilities to analyze situations and apply lessons to them (Taylor, 2017, p. 17-19).

In sum, the research emphasizes the benefits of inquiry based learning for students and testifies to its appropriateness within nearly any classroom, particularly a science-based one. Teachers who wish to employ the best methodologies and pedagogies available, per the scholarly literature, need to embrace this form of teaching (Harrison et al., 2017, xi-xii). Students benefit tremendously from it and it helps to promote many facets of learning and independence.

1.2.4. Science Laboratory

From this perspective, it is appropriate to assert that the inquiry based learning through laboratory experiments is the most effective learning platform for improving the attitudes and achievements of science education students in general science laboratory. The science laboratory is excellent because it allows students to embrace the principles and theories learned in the classroom and apply them to an actual seeing Meltzer, 2018, p. 1-3). Science is by definition experimentally-based and, therefore, to do it properly, students must be exposed to the laboratory setting frequently (Freeman et al., 2014, p. 8410). Science is based on the concept that experiment is the sole judge of what is determined to be scientifically true and untrue. Experiments within the laboratory show students, rather than just telling them, where the laws of science come from and allow students to see, firsthand, where the laws and premises of science come from (Tokuhama-Espinosa, 2015, p. 19).

Tokuhama-Espinosa (2015) explains that the research also indicates that the laboratory setting is the best possible environment for science education because it introduces learners not only to science, but also to the art of experimentation. Students learn to use a variety of complex skills, to include higher order thinking and abstract thinking skills, to design investigations and carry them out. The laboratory also promotes experimental and analytical skills, since students are exposed to a wide and diverse array of basic skills and tools used to carry out these tasks. Conceptual learning is also fostered in the laboratory setting, where students learn to master basic and more complex scientific concepts. The laboratory enables students to develop their collaborative learning skills through working with their peers to reach conclusions, make observations, analyze results, and develop new research questions (Tokuhama-Espinosa, 2015, p. 11-19).

1.3. Statement of the Problem

Interest has been considered as the main motivating factor that fuels the students' passion to pursue science. In this regard, teachers are seeking new ways to inspire their students to develop interest in the study of science in order to increase the rate of enrollment to departments as well as schools of science (Haug & Ødegaard, 2014, p.777). However, it is noteworthy that interest alone is not enough to produce good scientists, but rather the output of the students as well. Therefore, teachers also need to reconsider possible approaches that can enable their students to greatly improve their performance in science classes, which subsequently results in excellent performance by the students (Hayward & Laursen, 2014, p.14). Of specific interest in this case study is the transformation of the students' laboratory attitudes and achievement to better…complete sentence and need more quotes and description.

1.4. Purpose and Objectives of the Research Study

1.4.1. Research Purpose

The purpose of this research study is to investigate the effectiveness of inquiry based learning through laboratory experiments on the students' general science attitudes and achievements for science education students (Hong, et al., 2014, p.110). This is informed by the presumption that the learning approach adopted by both teachers and students in general science laboratory is extremely crucial in guiding the attitudes as well as the achievements of the students in science education (Hong, et al, 2017, p.2). Furthermore, this learning approach equally improve the activeness and participation of students during the learning process, which is quite important, considering the fact that laboratory experiments involve hands-on practicals in which the teachers test the knowledge and understanding of students in performing specific tests and experiments in the field of science.

1.4.2. Research Questions

Consequently, the research questions, based on the purpose and objectives of the research study will be given as follows:

1) What is the impact of inquiry-based laboratory experiments on student's general science laboratory attitudes?
2) What is the impact of the inquiry based learning strategy on the students' achievement in science laboratory experiments?

1.5. Scope of Work

The scope of work of this research study entails the effectiveness of learning models to the achievement and attitudes of the learners. It is worth noting that there are different learning models that scholars at different levels as well as fields can select in order to promote effective learning, as well as promote the adoption and development of positive attitudes towards the learning process. The main construct in this case is the level of interest that the learning model arouses in individual learners, which in turn makes them develop positive attitudes towards the learning subject, or topic, as well as significantly transforming their academic transcripts.

In this particular case, the research study focuses particularly on the impact of the inquiry based learning model by evaluating its effectiveness in transforming the learning attitudes as well as achievements of science education students especially when used for laboratory experiments classes (Preston, Harvie & Wallace, 2015). As such, the focus will be on how IBL transforms student's attitudes in science education, especially when used in laboratory experiments. In particular, the analysis will focus on how each construct of the IBL model facilitates positive learning among the students by transforming their attitudes regarding the learning topic as well as improving their academic performance significantly. can be better presented to cover constructs of the study!

1.6. Structure of the Dissertation

The research study is covered in five main chapters. These include introduction, literature review, research methodology, results and findings, as well as conclusions and recommendations as chapters one, two, three, four and five respectively. ***Chapter One*** is the Introduction, which introduces the concept of inquiry based learning, in addition to correlating it to the learning process, specifically for laboratory experiments for science education students. It also covers the background of the research study, the problem statement, as well as the research aims and objectives. ***Chapter Two*** is the Literature Review, which provides an analysis of existing data relating to the research topic, in addition to correlating the IBL model to the scientific method of learning. ***Chapter Three*** is the Research Methodology whereby the analysis in this case focuses on the processes and procedures followed by the researchers in collecting and analyzing the necessary data required in answering the research questions raised in the research study. ***Chapter Four*** is the Results and Findings section which is an analysis of the results obtained from the analysis of the data collected by the researchers from both primary and secondary sources. ***Chapter Five*** is the Conclusions and Recommendations section which provides closing remarks on the research topic in addition to giving appropriate recommendations regarding the research topic, especially for future research studies in the same field.

Chapter Two: Literature Review

2.0. Conceptual Framework

The conceptual framework of this research study lies on the fact that a learning outcome or achievement is significantly depended on the means of leaning used by the students (Hsu, Lai & Hsu, 2015, p.241). Furthermore, the research places significant emphasis on the adoption of the active form of learning as the most effective learning model that teachers should use, especially for learners in the science fields. Therefore, in this particular research study, it is clearly evidence that the adoption of the inquiry based learning laboratory experiments has an effective impact in the attitude and achievements of students in general science education (Hwang, Chiu & Chen, 2015, p.13). As such, it is noteworthy from the research question of the research study that a positive outcome from the inquiry based learning laboratory experiments will equally have a positive development in the attitudes and achievements of the students in the general science laboratory fields, such as improved performance and enhanced desire to learn.

The above statement is attributable to the wide range of advantages that learners enjoy because of the choice made by their teachers on the most effective type of learning model to adapt during the learning process (Hwang, et al., 2013, p.338). In this case, it is clearly evident that the choice of the inquiry based model of teaching and learning has very many benefits, which generally contribute to a positive outcome of the research study. In fact, relying on this perspective, the following are the presumed hypotheses of the research study.

2.0.1. Benefits of Implementing the Inquiry Based Learning Programs

As mentioned above, the inquiry based learning model is widely accepted and used in most learning settings because of the numerous benefits accrued from the adoption of the teaching and learning model (James, Rabe & Rosen, 2013, p.5285). One of the main reasons why this model of learning is widely used across various learning platforms, such as this one involving laboratory experiments is based on the fact that the learning models is student based. Therefore, as a student centered form of learning, the model concentrates on the students, specifically with the intention of significantly improving the scope of knowledge for the student after the learning session (Ji-Wei, Tseng & Hwang, 2015, p.282). The inquiry based learning model achieves this through the development of questions regarding a new subject or topic of study, which in turn arouses the curiosity of students to find the right answers to these questions, and to find the answers fast.

Consequently, one of the main advantages of the inquiry based learning model in teaching students is the fact that it leads to a higher level of motivation among the students (Johnson & Cuevas, 2016, p.51). As mentioned above, the questions asked by students before the start of the new subject or new topic in class makes them very curious of what they are about to study, and as such, will look forward to obtaining the right answers to these questions sooner rather than later. Therefore, the students will be highly motivated in any class as long as they are curious to find out the right answers to their questions (Kazempour & Amirshokoohi, 2014, p.285). The inquiry based learning approach eventually provides the students with the much needed answers to their questions, which further improves their level of satisfaction in learning largely exhibited through development of positive attitudes and excellent performance by the learners.

Another benefit that accrues to learners due to their selection of the inquiry based model of learning is that students greatly improve their critical and creative thinking skills (Koksal & Berberoglu, 2014, p.66). Critical and creative thinking (CCT) is an instrumental concept of learning as it enables the learners to think outside the box by brainstorming answers and solutions to the problems presented to them during classroom sessions. As such, a critical thinker is more averse regarding the adoption of new ideas and new principles relating to a subject or topic of learning within classroom setting as opposed to a non critical thinker (Ku, et al., 2014, p.251). In this regard, it is evident that the curiosity levels raised within the students through the inquiry of various key objectives of a new subject or new topic are the main determinants that promote the development of critical and creative thinking skills.

Other advantages that students draw from the adoption of the inquiry based approach as the most effective model of active learning as argued by Lai, Guo & Tsai (2014, p.436) includes the fact that it helps learners to develop their literacy in information, improves the level of information retention among the learners, deepens the understanding of learners in specific subjects and topics, encourages self-direction, reinforces growth in the physical, emotional as well as cognitive perspectives, in addition to encouraging the development of both interpersonal and team skills. In fact, Lau, Lui & Chu (2017, p.533) support the idea that inquiry based learning places more emphasis on the intrinsic rewards of learning rather than the extrinsic rewards of learning further improves the outcomes and attitudes of learners in this field, giving them an opportunity to teach one another as the learn from each other, validating the knowledge and experiences from all students in the classroom, and setting a suitable learning pace for all learners in a classroom.

Hallinger et al. (2017, p.255) note that reforms in problem-based learning have emphasized the need to go beyond simply teaching students information to making them take ownership of their learning through engaging in a process that uses identified issues to increase skills, knowledge, and critical-thinking skills. Reforms have focused on improving the following areas. First, problem-based learning has to be learner-centered and learner-driven. It is the learner, and not the teacher, who sets the goals and outcomes. Second, Pedaste et al. (2015, p. 47) highlight that, while groupwork is appreciated and highly-encouraged, the students must be independent work prior to working with other people. It is the process of working independently to problem solve that adds values. Third, even when it is time to engage in group work, it should be done in small groups with a teacher present to facilitate discussions. These reforms in problem-based learning are centered on allowing the students maximum opportunities to engage in self-directed learning.

2.0.2. Inquiry Based Learning in Sciences

The sciences are dedicated to systematically studying the structure and the behaviour of the natural, physical world. This is done through both observation and experimentation (Lederman et al., 2014, p. 9). The sciences are both intellectual and practical activities, which are well-suited for hands-on research and discovery. Many educators of the sciences opt to employ inquiry based learning into their classrooms (European Commission, 2007, p. 1-3). Inquiry based learning is ideally a collaborative effort bringing together all the stakeholders in a learning setting, who include the students, their teachers, their parents, as well as the school administrators, among many other stakeholders (Laursen, et al., 2014, p.406). All these stakeholders benefit greatly from their collaboration through inquiry based learning, whereby key among these benefits include an opportunity to access a wide range of resources, learning support drawn from various technologies used in teaching and learning, as well as increased opportunities for creative synergy and collegial problem solving. The model also results in enriched teaching and better learning for the students through the promotion of learner centred planning and the elimination of bureaucracies, over regulation, and hostilities in learning (Lazonder & Harmsen, 2016, p.681). Consequently, as the main participants of the inquiry based learning model, considering the fact that it is a student centred approach; the learners get to acquire much needed skills that they can apply everywhere, such as using the CCT skills in problem solving.

2.1. The Scientific Method

The most conventional learning model that would be considered appropriate for laboratory experiments would be the scientific method, as opposed to the inquiry based learning model being proposed in this research study (Linn & Jacobs, 2015, p.272). In fact, the scientific method of learning is still being widely practiced in many learning institutions supporting the study of science and related courses. The scientific method of learning primarily refers to a broad framework that enables individuals to study and learn more about their surrounding worlds in a scientific manner (Maaß & Artigue, 2013, p.779). As such, the scientific method entails a series of absolute and unchangeable procedures which act as a guideline to the preferred method for use in order to reach an acceptable scientific theory regarding to a specific subject matter. In this regard, the scientific method rarely provides a finite number of steps or an exact procedure for learners to follow in a specific learning scenario, but rather highlight some of the commonly used mechanisms that students should follow when conducting a scientific inquiry.

There are five basis steps that students should follow when analyzing a topic or a concept using the scientific method of learning (Maaß and Doorman, 2013, p.887). These steps include making an observation, forming a question, forming a hypothesis, conducting an experiment, analyzing the data and drawing a conclusion. From this perspective, it is clear that the scientific method is an evidence based model of learning which banks on the availability of evidence to support a particular premise or finding from a research topic (Marshall & Alston, 2014, p.807). As such, the steps mentioned above are instrumental in guiding the students to obtain the best results as evidence in support of their premise in the research study.

According to Abdi (2014, p.8-12), inquiry based learning compliments the scientific method, and the scientific method process both corroborates and enhances inquiry based learning. The scientific process is centered on individuals engaging in hands-on work. Students make observations and, from these observations, they form questions and hypotheses. Inquiry based learning allows students the opportunity to come up with their own questions and hypotheses, rather than passively respond to those formulated by a third party, such as an educator. Again, the goal is to make students take an active role in their learning process and guide their education through their own observations, inquiries, and discoveries. Inquiry based learning and the scientific method both are compatible with these educational goals, particularly when they are carried out within a laboratory setting. The end result is students who are better prepared to take the learning initiative on themselves and who are motivated to learn through discovery (Erduran et al., 2014, p. 3-5).

2.2. Collaborative Learning Cut across Inquiry Based Learning

Cognitive learning refers to a function based model of learning which reviews how an individual processes or reasons with information at his or her disposalRef. As such, it revolves around a number of factors including problem solving skills, retention of memory, thinking skills, as well as the perception of learned material. In this regard, the construct of cognitive learning cuts across inquiry based learning in the sense that it provides the learners with a set of problem solving skills, which they later apply in the undertaking of answering the questions raised (Tamim, 2016, p.12). The cognitive learning concept also empowers the learners with the capacity to retain their memory, gain an additional set of thinking skills as well as improve the learner's perception to the course material. Therefore, in this case involving inquiry based learning; it is evident that cognitive learning promotes the application of the inquiry based learning construct.

Content learning is whereby the learners are furnished with the necessary content required to cover a particular topic of research, or to answer a set of questions. Therefore, content based learning cuts across the inquiry based learning approach in the sense that it provides the scholars with the right amount of content necessary in answering the questions raised at the start of the study topic or the learning subject (Stokhof, et al., 2017, p.116). In this case, when the students are furnished with the right content, hereby referring to the course materials as well as other supplementary reading material required in answering a particular question or a set of questions designed during the start of an inquiry based learning, then the students will be on the right path to obtaining that which they seek most, which is knowledge and understanding through inquiry based learning. Therefore, in order for learners to benefit from the content learning approach, they must have access to the right type or framework of learning material or content.

Collaborative learning refers to an educational approach to both teaching as well as learning that involve two or more students working together in groups in order to solve a problem, complete a task, or to create a product. In this case, collaborative learning cuts across inquiry based learning as it provides learners with a platform upon which they can advance their research work thereby being in a position to answer the related questions appropriately (Thaiposri and Wannapiroon, 2015, p.2137). Through collaborative learning, the scholars get another informative approach towards their new learning models. In addition, collaborative learning also enables students to assist one another or to support one another in the tackling of the questions raised earlier during an inquiry based learning. As such, this will enhance the output of their learning approach as they will be able to collaborate their answers to the questions, especially if the questions were similar, to allow them come up with the right answers to the questions, thereby furthering their question of knowledge and learning.

2.3. The Results of Previous Studies

The results obtained from previous research studies confirm that the adoption of the inquiry based model of learning is effective in promoting the learning outcomes of students in a classroom setting. The reason for this assertion is because the learning model empowers the learners to seek knowledge by themselves as opposed to relying on their teachers or instructors (Yakar and Baykara, 2014, p.2). The student based learning approach further enables the learners to focus on getting the right answers to the questions, in addition to promoting their comprehension and understanding of the study subject. The learning approach facilitates a deeper understanding of the learning topic, in addition to promoting the achievement of a spectacular outcome in the learning process.

In the same regard, previous research studies further confirm that learning through inquiry based learning platforms enables students to be high achievers in their learning processes compared to other students who use different platforms of learning. The reason for this assertion stems from the fact that most of these learners will know how to enjoin other learning models in order to succeed in their classes (Zafra-Gómez, et al., 2015, p.1050). Examples of the additional learning models introduced in this case include the content learning method, the collaborative learning method, as well as the cognitive learning method. Therefore, the incorporation of all these methods of learning in the within the inquiry based model of learning would be instrumental in promoting better outcomes and positive results of the learners.

In addition, it is worth noting that the inquiry based learning model correlates closely with the scientific method of learning, and as such, both team up in providing the most superior results required in conducting a particular research study, especially considering the construct of learners. According to Almuntasheri et al. (2016), the learning model is particularly effective in promoting the achievement of the best results in a learning outcome, churning the students into becoming very bright and high performing high achieving learners. Furthermore, the learning platform also helps slow learners get over their weaknesses in research, comprehension, as well as learning, thereby subsequently improving their scores and performance within the classroom setting.

IBL is a pedagogical approach that is widely advocated, but little knowledge exists on its application in higher education. In their study, therefore, Aditomo et al. (2011) examined the subject among 224 university teachers from Australia. Despite the diversity of language and tasks put forth as IBL, the university teachers shared a broad conception of inquiry. In addition, the study found that IBL is practiced in many disciplines, across different class sizes, and also in universities that do not have a lot of emphasis on research (Aditomo et al. 2011). This latter was an important finding because the Boyer Commission had advocated for the use of IBL as the standard in research universities (Aditomo et al. 2011).

In addition, an evaluation of four IBL workshops hosted annually from 2010 to 2013 to introduce teachers to IBL teaching, Hayward and Laursen (2014) found that most participants subsequently implemented IBL in their classes, at least one type of IBL technique one year following a workshop. A number implemented both the IBL technique and the traditional method in the classes, while others started off with the traditional method and gradually phased it out to replace with the IBL teaching method (Hayward & Laursen 2014).

Most importantly, the majority of participants reported decreased use of lectures and solving problems on the board, and increased frequencies of students-led classroom discussions, collaboration among students in small groups, and more presentation of proofs by students; signifying a move to student-centered activities rather than activities centered on the teacher (Hayward & Laursen 2014). Interestingly, participants perceived IBL to be a broad spectrum of practices and were thus more comfortable utilizing elements of IBL in their classrooms rather than the full spectrum at once (Hayward & Laursen 2014).

Significantly, IBL studies have also been conducted among students. The objective of Kogan and Laursen (2014) study, for example, was to examine the effectiveness of inquiry based learning (IBL) in subsequent grades in college mathematics among undergraduate students. Hence, Kogan and Laursen (2014) study was important because it compared subsequent grades by the type of course (IBL versus non-IBL) and by gender. In addition, the study examined the impact of IBL on students who had previously been achieving low grades.

Kogan and Laursen (2014) found that IBL students took more leadership roles in class and were also more inquisitive. In addition, IBL students gave other students feedback on their assignments and greater intellectual input was evident. Among women, IBL promoted collaboration, communication, and problem solving. Among low achievers, however, the effects were more pronounced; study habits and problem solving skills became more entrenched.

In Abdi (2014), the purpose was to examine the impact of inquiry based learning on 40 fifth grade students' scores in two science classes. The experimental group went through eight weeks of inquiry based learning while the other group went through traditional learning for a similar period. The study found that IBL students achieved higher scores compared to students in the traditional class (Abdi 2014).

As Abdi (2014) observes, IBL-based science education allows students to engage with similar processes as scientists do as they develop knowledge. Traditional practices of teaching that emphasize scientific facts, lectures, and textbooks, are replaced with inquiry-based methods that engage students, allow students to gather evidence with laboratory techniques, expect students to problem solve using evidence and logic, and encourage students to explain their conclusions (Abdi 2014). In essence, students justify their knowledge as a scientist would. In contrast, traditional classrooms largely un-involve students. A traditional classroom is unilateral teaching, a one person show that expects students to accept instruction blindly without question (Abdi 2014).

As such, it is appropriate to assume that the IBL model is important for the UAE as a country as it gives priority for education development, especially with regard to the curriculum, the education system, as well as the taking of international tests by students, such as the TIMSS and the PISA tests. Educational experts in the UAE consider the IBL model as a crucial instructional approach to teaching students as it also facilitates the implementation of educational reforms, not only within the country, but also across the globe. This is largely informed by the fact that IBL enhances the scientific skills of students as well as supporting their abilities in improving their academic scores, both within the national curriculum, as well as in international exams such as the TIMSS and PISA tests (Savery, 2015). In this regard, it is worth noting that the best approach for teaching subjects in the science education field is through IBL instructions, whereby the students conduct investigations through three main dimensions, namely inquiry, cognitive, as well as content.

Consequently, it is worth noting that the implementations of the IBL model in the UAE will be instrumental in promoting the academic performance of students across all educational levels, in addition to transforming their attitudes towards their respective learning subjects positively. This is especially with regard to the fact that the IBL model arouses curiosity among the learners, which in turn develops into interest in the respective learning subject as the students spend tons of private hours researching on a given topic or subject (Sever & Guven, 2014). Therefore, the IBL model would definitely promote educational development in the UAE by enabling the education stakeholders to develop the right curriculum for the students, as well as upgrading the prevailing education systems in the country. Notably so, the students will also improve their academic performance significantly in such a way that they will be in a position to excel in both local tests as well as international tests, such as the case of TIMSS and PISA.

2.4. UAE Science Education Reform

Hourani et al. (2018, p. 2-4) add that the government of the UAE has taken significant measures to augment the quality of education students receive and to ensure that the schools are using the most appropriate and up-to-date curriculum so that students receive the best education possible and can compete on the global scale. Of special interest to the government is improving education in STEM studies. The Ministry of Education recognized that these subjects are what students need to be marketable in the international job market. Best practices are currently being studied and assessed regarding how STEM education can be improved. Significant resources are being allocated to improving the curriculum and educating teachers on how to improve their pedagogies. Inquiry based learning has been identified as a major step in the right direction, particularly for improving STEM education.

Chapter Three: Methodology

3.0 Methodology

The research was carried out over a period of ten weeks in a private school in the United Arab Emirates that teaches science using the scientific method and implementing inquiry-based learning. The results of the study mainly focus on students' achievement in science laboratory experiments and their attitude. Quantitative and qualitative methods were used to collect data. First, the students' scores were collected and second, a student survey was administered to know the students' experiences and attitudes. In this chapter, the population and sample, research design, instrumentation, data collection, and data validity are presented. Furthermore, the ethical considerations are also presented.

3.1 Research Design

A mixed-method design is used to explain and explore the effectiveness of inquiry-based learning in teaching science. Mixed methods research use quantitative and qualitative methods to generate data that is analyzed for conclusions that are based on scientific results (Ponce, & Pagán-Maldonado, 2015, p.111). Quantitative methods produce numerical and statistical data from experiments or case-control. Qualitative methods produce nonnumeric data from field observation, interviews and surveys (Hansen et al. 2016, p.492). Researchers who have explored the advantages of using mixed methods research designs have cited a number of positive attributes. The first attribute lies in the ability of mixed methods design to enable researchers to fully decipher the phenomena they are studying. Of most significance is the ability of the mixed methods research to add value to research by enhancing the validity of results. Mixed methods integrate quantitative and qualitative research methods (Ertmer, Schlosser, Clase & Adedokun, 2014, p.9). Readers are likely to be confident in the results and conclusions presented because of the integration component of mixed methods research. Integration also gives readers and researchers to check whether the data provided by the quantitative and qualitative research is complementary. Deductive and inductive reasoning are prompted simultaneously, therefore, allowing the researcher to deepen their understanding of the issue under study. Improving the quality of education is a complex issue that involves the interaction of different issues. The qualitative component of mixed methods research enables researchers to collect information on topics that do not have information from prior researches. The topic of the impact of inquiry based learning on the score outcomes and perceptions of students in the UAE does not have a significant amount of data to enable one to reach an informed hypothesis. As such, mixed methods research will be appropriate in collecting and recording information about the attitudes and perceptions towards class subjects by the students in UAE. Teaching and learning also involve psychosocial factors because of the human interactions between teachers and students and among students. Using qualitative methods to conduct the research would have captured psychosocial issues like attitudes and perceptions while leaving the numeric data involved without analysis (Powell & Arriola, 2003, p.178). It also involves issues like scores and frequencies which can be captured numerically in a clear and precise manner. Using quantitative methods alone would assist in the analysis of the numerical data while being unable to capture the dynamics generated by human-human interactions (Daniel, 2016, p.92). Data on the psychosocial dynamics and numeric figures is required to reach well informed conclusions. Therefore, using both qualitative approaches and quantitative approaches was necessary for this study.

The research study was conducted both concurrently and sequentially in four stages. The concurrent data was collected quantitatively and qualitatively at the same time where the sequential data are collected one after the other. The first stage involved the administration of a pre-test to both groups. The purpose of the pre-test was to assist in assessing and recording the ability of the students before the introduction of IBL into the lessons of the intervention group. The performance of the students was graded against a rubric showing the justification for awarding points to the students. The rubric also showed the specific skill tested by each question. The second stage involved testing the processing and evaluating skills of the students by examining how they would handle five issues during experiments they conducted in the lab over the course of eight weeks. The first issue that was tested involved how the students presented collected and transformed data. The second issue involved how the students interpreted data and outlined results by applying scientific reasoning. The third issue involved analyzing the outcomes of investigations and discussing the validity of the outcome-based predictions the students made. The fourth issue involved how the validity of the used method was discussed and lastly how improvements or additions to the method were described by the students. Field observations were also conducted by the researcher during the second stage. The researcher observed mannerisms displayed by students in the two groups during their lessons. The mannerisms were indicators of the students' involvement as they were being taught. The third stage involved administration of a post-test to the two groups of students. The intervention group had been taken through their experiments using inquiry based learning while the control group had been taken through traditional teaching methods. The assessment of the tests was done using a rubric which guided the allocation of points to students. The rubric also indicated the specific skills tested by each question. The fourth stage involved distribution of close ended questionnaire to students in order to investigate their perceptions and experiences during the science classes. The questionnaire contained questions similar to the ones administered during surveys for

Longview Independent School District (LISD). The answers were categorized to reflect strongly agree, agree, disagree, and strongly disagree.

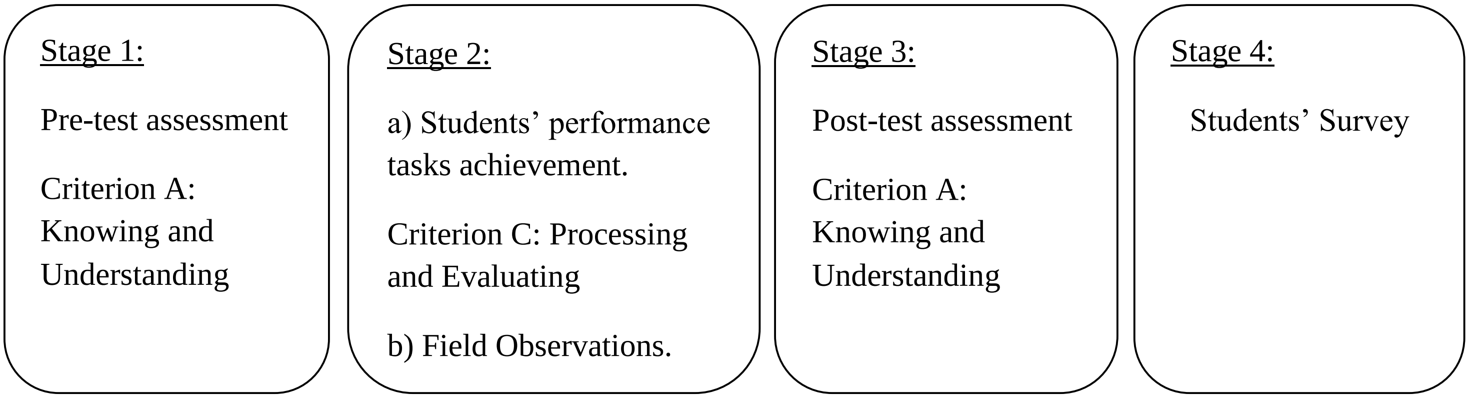


Figure 1. The research design of this study

3.2 The Population of the study

The participants of the study are two groups; grade 6 science teacher (1), and grade six students (47) in the girls section of the school. The study identifies and measures the students' attitudes and achievements.

3.3 The Samples Selected

The sample of the study is a representative sample. The participants in the study belonged to grade 6. Grade six students in the school are five streams with 24-25 students in each one. Two streams were selected for the study. Grade 6B represents the intervention group (23 girls) while section C represents the control group (24 girls). In both section the students were from different achievement level (high – medium- low), no special needs students in the sample selected.

3.4 Instrumentation

Multiple tools are used in this study; students' survey, students' scores and field notes. The first tool administered in this study was the pre-test that was used to measure students' achievement before the intervention of IBL strategy. The pre-test contained multiple scientific questions. The second step involved the implementation of inquiry based learning through lab experiments and investigations for the intervention group. Four experiments were conducted based on principles of IBL through the course of ten weeks. The control group was taught using the traditional way of learning which did not involve practical work but rather used worksheets and power point presentations. At the end of ten weeks a post- test was administered to students in both groups. Rubrics were used to measure students' performance after the tests were marked. The test scores were a direct reflection of the students' abilities in relation to retention of information and application of scientific knowledge. A students' survey was also used to evaluate the students' experiences and perceptions in the control and intervention group. The survey questions were close ended for uniformity of data collected and ease of comparison and analysis. Last, field observations during the classes were used to determine the students' level of engagement during lessons for both groups. Three field observations that lasted for forty five minutes were done for each group. The researcher observed the behavior of students in class and asked the students questions on how they respond to different learning related scenarios as they are being taught in class. The answers were classified into five categories of very high, high, medium, low and very low.

3.5 Data Collection Method

For the research, primary data was collected in four stages. The outcome of the first stage was test scores for the pre-test assessment. Sample questions included: During which phase of the Moon does a solar eclipse occur? Which of the following is an example of water changing its phase? The control and intervention group took tests that assessed different scientific skills among the students. For instance, question 4 and 8 tested the students' ability to recall scientific knowledge. Question 2, 7 and 25 tested the students' ability to use information to make judgments. The points awarded after the tests were guided by a standard rubric. The third stage was similar to the first stage where the post test scores were the outcome. The rubric also guided the points allocated to the students for the post test.

The second stage had outcomes which included remarks from the field observations and results from lab experiments. The remarks were concerned with the mannerisms and perceptions to learning exhibited by the students. The field observations were collected through direct observations and individual interviews where the students were asked different questions. Direct observations involved five mannerisms. The first mannerism to be checked was the positive body language of the students. The specific directive for observing was checking whether the students were exhibiting body postures that indicated that they were paying attention to the teacher and or other students. Consistent focus was the second behavior exhibited by the students to be checked. The specific directive for observing was to check whether all the students were focused on the learning activity with minimum disruptions. Verbal participation was the third behavior to be checked. The researcher was supposed to listen to decipher whether students were able to express thoughtful ideas, questions, and reflective answers that were appropriate and relevant to learning. The level of confidence exhibited by the students was the fourth issue to be checked. The researcher was supposed to check if the students exhibited confidence and could initiate and complete tasks with limited coaching while being able to work in group settings. The last behavior to be checked was the excitement and fun in terms of the enthusiasm, interest and positive humor expressed by the students.

The perceptions of the students were analyzed using interview questions which assessed individual attention, clarity of learning, meaningfulness of work, rigorous thinking and performance orientation. Individual attention displayed by the students indicated whether the students felt comfortable asking questions whenever they needed to seek help. The interview question attached to the given description was: What do you do in class if you need extra help? The clarity of learning during lessons was measured by whether the students could describe the purpose of the unit or lesson. The question attached to investigating clarity of learning was: What are you learning? Is this work interesting to you? Do you know why you are learning this? The students were assessed to investigate if they employed rigorous thinking during class. Rigorous thinking should have been indicated by students having the ability to work on complex problems, come up with original solutions, and have a reflective outlook toward their work quality. The question used to investigate rigorous thinking was: How challenging is this work? In what ways do you have the opportunity to be creative? Performance orientation was the last perception of the students to be checked. Performance oriented students should have had the ability to understand the characteristics of high quality work and describe the criteria by which their performance would have been evaluated. The question to analyze students' performance orientation was: How do you know you have done good work? What are some elements of quality work? Answers to the questions were grouped into very high, high, medium, low and very low.

Additionally, the second stage involved results from four lab experiments. The topic of the first experiment was 'How does thermal energy move?' The topic for the second experiment was

‘Identify the best insulator’, ‘Physical changes’, and ‘Chemical changes’ in that order. Students in the two groups were allocated points according to the experiment reports they submitted. A rubric guided the allocation of points to the students’ projects. The points were matched with concurring skills and ranged between 0 and 8. 0 corresponded with students’ skills below all the skills described in the rubric. 5 corresponded with the students’ abilities to state and use scientific understanding to solve familiar problems and make judgments. 8 corresponded with students’ abilities to make judgments supported by science by interpreting information.

The fourth stage involved a survey whose outcome was answers to questionnaires. The questionnaire had questions about how they perceive science for students in both groups. Sample questions included: I usually understand what we are doing in science, and being a scientist might be fun. The questions are close ended and the answers have to be either strongly agree, agree, disagree or strongly disagree.

3.6 Validity of the Study

The internal validity of the study is high because there is great correspondence between the study and the data collected (Zohrabi, 2013, p.258). Both qualitative and quantitative procedures offer high internal validity. The perceptions and attitudes of the students were captured in the form of answers to an interview and a questionnaire. The external validity displayed by the study is high despite qualitative studies having low external validity because the numeric issues investigated occur in other students’ populations. The researcher has high inference validity for this study because the data that was captured reflected the qualitative and quantitative issues surrounding introduction of inquiry based learning to schools in the UAE. Statistical analysis of quantitative data and visual expression of qualitative data should offer a clear picture of the research question to the researcher.

3.7 Ethical Considerations

All researches involving underage children should adhere to Articles 12 and 3 as they are stated in the United Nations Convention in relation to children's rights. Article 3 demands that the primary considerations during research be the interests of the children. Article 12 demands that the right of expression should be granted to children who can come up with their own views about issues that affect them, commensurate with their maturity and age (Pillay, 2014, p.195). The ethical considerations involving an educational research are necessary and should be adhered to because of the sensitive nature of conducting researches within schools where there are underage students. Researchers have the mandate to be ethical and treat every individual involved in their study with respect. Involved individuals should be treated kindly, with respect despite their age, ethnicity, gender, race, cultural identity, political belief, disability, partnership status, and faith (Ramrathan, Le Grange & Higgs, 2017, 197). All individuals, regardless of whether they are direct or indirect participants, should be treated under the described code of ethics. The researcher should work while upholding the protection of the students from danger and harm. The students involved in the research should have consent from their legal guardians or parents to participate in the research (Bourke & Loveridge, 2014, p.152). Consent should be sought without any pressure or making the students or parents or guardians feel like they will be reprimanded for not participating in the study. It is also expected that the researcher will inform the participants of their right to withdraw from participating anytime they may wish to do so (Govil, 2013, p.18). Consent should also be provided to the researcher by the school's administration. The researcher should also adhere to rules which require supervision from relevant school authority when conducting the research. It is also the role of the researcher to make sure that their assistants are in compliant of laws that guide interactions between researchers and students. It is also the role of the researcher to ease participants from any stress or discomfort that may arise from activities like interviews related to the research. Researchers' activities like questionnaires and surveys should not in any way add to the workload or interfere with the normal working of the participants. A researcher has to be careful in case he or she decides to use incentives to encourage students to participate. For instance, a researcher is not supposed to offer sweets to children or any substance that can affect the health of the involved children negatively. Participants in the research should be treated with confidentiality and anonymity. Only guardians have the authority to waiver the rights to confidentiality and anonymity of their children. Even so, the waiver has to be in written form. It is also the right of participants to be associated with research for their input if they wish so. Researchers are also expected to adhere to data protection laws in relation to how they store and use personal data about the individuals who participate in their studies. Lastly, researchers are expected to maintain integrity by refraining from; falsifying findings, distorting findings by selective publishing of findings, working on research one is not qualified to conduct and employing research for illegal purposes.

Chapter Four: Data Analysis and Results

4.0 Data Analysis

Data obtained from the study underwent different statistical manipulation to come up with required results. The statistical software IBM SPSS Statistics 22 was used in performing some of these statistical analysis. The analysis of data focused on four broad categories which are:

The first category is Criterion (A) which measured the achievements of the students' during the pre and post-test. Additionally, in this category the analysis also considered the differences and relationship between the control and intervention group.

The second category is Criterion (C) which measured student's achievement in conducting four laboratory work sessions that were placed within a period of two months. A comparison of the control and intervention groups was also considered in this part of the analysis.

The third category is field observations, where we consider data collected by the researcher while observing the participants conducting the experiments in Criterion C.

The fourth category is the student survey analysis that considers the differences in the perceptions and opinions on science by participants in the control and the intervention group, at the end of the study.

4.1 Data Analysis of Criterion A (Pre-Post Test)

The first step in the data analysis was to come up with the descriptive statistics for the pre and post test datasets. The datasets included data from 47 participants, 24 of whom were in the control group and 23 in the intervention group.

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
PRETEST	47	1.00	5.00	105.00	2.2340	1.08773	1.183
POSTTEST	47	1.00	7.00	182.00	3.8723	1.55503	2.418
Valid N (listwise)	47						

Table 1. Descriptive Statistics of the Pretest and Posttest

In the pretest the highest score observed was 5.00 while the lowest score observed was 1.00, and an average score of 2.2340 was observed in this stage. In the posttest the highest score was 7.00 while the lowest was 1.00, with a mean score of 3.8723. The standard deviation shows that our scores are not too close to the mean, and that they are spread across the values above the mean, or below the mean. . Based on the pretest and posttest descriptive statistics shown above one can make a mere observation that there was a positive change in outcome from the pretest to the posttest.

However, such an observation may be considered inadequate in proving that inquiry based learning was effective in increasing knowledge and understanding, based on the pretest and posttest. A test to compare the means between these two groups can help in deciding if the observed improvement or differences from the pretest to the posttest can be attributed to the learning intervention. A paired samples *t*-test, yielded the following results:

Paired Samples Test									
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 PRETEST - POSTTEST	-1.63830	1.18735	.17319	-1.98692	-1.28968	-9.459	46	.000

Table 2. Paired Sample *t*-test of the Pretest and the Posttest

The two tailed paired *t*-test (df =46) shows a significant positive change between the pretest and the posttest (t = 9.459; $p < 0.01$). Since the p value is less than 0.05, the difference between the pretest and the protest is highly statistically significant and therefore the observation we made earlier is not merely due to chance.

Having identified the significant change between the pretest and the posttest, it is now crucial to test if there is a difference between the control and intervention groups with respect to the changes or difference observed from the pretest to the posttest. Descriptive statistics for the control and intervention group were obtained as follows:

GROUP	Mean	Std. Deviation	N
Control	.8333	.70196	24
Intervention	2.4783	.99405	23
Total	1.6383	1.18735	47

Table 3. Descriptive Statistics for the Control and Intervention Group

From the descriptive it is clear that there is a difference between the control and the intervention group, where the intervention group showed better outcomes. In this stage it is also necessary to determine if the null hypothesis that suggests that the error variance of the dependent variable is equal across groups which in this case is the control and intervention group is true. The results of the Levene's Test of Equality of Error Variances are:

F	df1	df2	Sig.
3.066	1	45	.087

Table 4. Levene's Test of Equality of Error Variances

The p value in this case is 0.087 which is greater than the significance level of 0.05. As such the null hypothesis cannot be rejected; we accept the null hypothesis and therefore agree that in the intervention and control groups of this study, the error variance of the dependent variable is equal. Therefore, the equal variance between these two groups means it is appropriate to conduct a test of between-subjects effects.

As it was the case in the pretest and posttest, it is also necessary to determine if the difference observed between the intervention and control is statistically significant. A univariate analysis or ANOVA was performed with the dependent variable being the difference between the posttest and pretest. The results of ANOVA are provided in table below.

Tests of Between-Subjects Effects

Dependent Variable: DIFFERENCE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	31.779[a]	1	31.779	43.240	.000	.490	43.240	1.000
Intercept	128.800	1	128.800	175.251	.000	.796	175.251	1.000
GROUP	31.779	1	31.779	43.240	.000	.490	43.240	1.000
Error	33.072	45	.735					
Total	191.000	47						
Corrected Total	64.851	46						

a. R Squared = .490 (Adjusted R Squared = .479)

b. Computed using alpha = .05

Table 5. Tests of the relationship between Control and Intervention Groups

The source we are interested in is the third row, GROUP. The results of the test ($F = 43.240$, $p < 0.01$) suggest that there is a statistically significant difference between the control and the intervention groups of the study. Therefore, the intervention group had an obvious improvement from the pretest to the posttest when compared to the control group. This observed difference is significant and can be attributed enquiry based learning as opposed to any other extraneous factors or variables. The graph below shows the difference observed between the control and the intervention group.

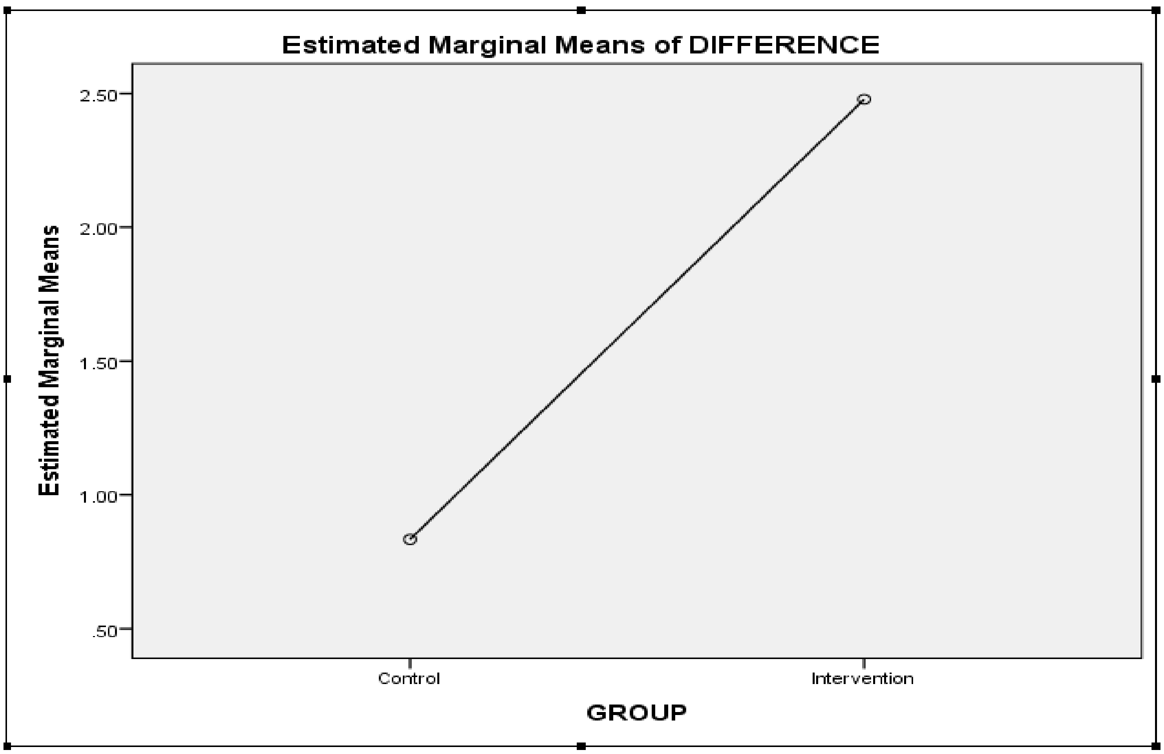


Figure 2. Estimated Marginal Means for the Control and the Intervention Group

4.2 Data Analysis of Criterion C

In analyzing data in this section, four different datasets were considered. These datasets represented the four laboratory work sessions that focused on how thermal energy moves, identification of the best insulator, physical changes and chemical changes. In this analysis a comparison of outcomes was done between the first experiment (CRITERION_C_SEPT_29) and the second experiment (CRITERION_C_OCT_13). The descriptive statistics for the data in this paired sample showed that in the first experiment the mean was 3.4681, while in the second experiment it was 3.8085. Based on the findings, one can say that the students had an improved average performance in the second experiment when compared to the first experiment. To prove that the improvement represented a significant change, a paired sample t-test was conducted:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	CRITERION_C_SEPT_29 - CRITERION_C_OCT_13	-.34043	.89142	.13003	-.60216	-.07869	-2.618	46	.012

Table 6. Paired Sample t-test of the First and Second Experiment

The two tailed paired *t*-test (df = 46) proves that a statistically significant difference was observed between these two experiments (t = 2.618, p = 0.012).

A second comparison was done to test if the students' outcomes showed any improvement from the second experiment (CRITERION_C_OCT_13) to the third experiment (CRITERION_C_NOV_22_P). The descriptive samples for this pair were characterized by a mean of 3.8085 for the second experiment and a mean of 4.4043 for the third experiment.

The significance test gave the following results:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	CRITERION_C_OCT_13 - CRITERION_C_NOV_22_P	-.59574	1.05624	.15407	-.90587	-.28562	-3.867	46	.000

Table 7. Paired Sample t-test of the Second and Third Experiment

Based on the two tailed paired t-test (df = 46) the difference between the two experiment was highly significant (t = 3.867, p < 0.01).

The last comparison was made between the second experiment (CRITERION_C_OCT_13), and the fourth experiment (CRITERION_C_NOV_22_C) that was done on the same day as the third experiment (CRITERION_C_NOV_22_P). The mean difference in student outcomes in these two experiments was very small. The second experiment had a mean of 3.8085, while the mean in the fourth experiment was 3.8936. The two tailed paired sample test (df = 46) showed that there was no significant difference between these two experiments (t = 0.530, p = 0.598). The p value is greater than 0.05 and hence the slight difference between the two experiments is not statistically significant.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	CRITERION_C_OCT_13 - CRITERION_C_NOV_22_C	-.08511	1.10000	.16045	-.40808	.23786	-.530	46	.598

Table 8. Paired Sample t-test of the Third and Fourth Experiment

Having determined the relationship between these different laboratory experiments it is now necessary to determine the role and relationship of the control and intervention groups in the differences experienced between the experiments. The first step will be to consider whether the error variance of the dependent variable is equal across groups. The group in this case is the control and intervention group, while the dependent variables are the difference between the experiments comparisons considered in the analysis above. The results for three Levene's tests are shown below:

1. DEPENDENT VARIABLE: (2nd Experiment- 1st Experiment)

F	df1	df2	Sig.
3.359	1	45	.073

2. DEPENDENT VARIABLE: (3rd Experiment – 2nd Experiment)

F	df1	df2	Sig.
.012	1	45	.911

3. DEPENDENT VARIABLE: (4th Experiment – 3rd Experiment)

F	df1	df2	Sig.
.235	1	45	.630

Table 9: Levene's Test of Equality of Error Variances

The p value in all three instances are greater than 0.05, and hence we accept the null hypothesis and agree that in the intervention and control groups the error variance of the dependent variable is equal and hence a test of between-subjects effects can be conducted.

The univariate analysis or ANOVA will be used testing for these between-subjects effects. The results of the tests are, ($F = 1.592$, $p = 0.214$) for the comparison between the 1st and 2nd experiment (Table 10). ($F = 4.362$, $p = 0.042$) for the comparison between the 2nd and 3rd experiment (Table 11), and (F = 10.319, p = 0.002) for the last comparison between the 2nd and 4th experiment (Table 12). The results for the first comparison suggest that the differences observed between the 1st and 2nd experiment cannot be proved statistically, and the may be attributed to other extraneous factors as opposed to only being caused by the learning intervention. The other two comparisons suggest that there is a statistically significant difference between the control and the intervention groups of the study, and this can be attributed to improvement as a result of using the inquiry-based learning model.

Tests of Between-Subjects Effects

Dependent Variable: DIFFERENCE_1_C

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	1.249[a]	1	1.249	1.592	.214	.034	1.592	.235
Intercept	5.334	1	5.334	6.799	.012	.131	6.799	.723
GROUP	1.249	1	1.249	1.592	.214	.034	1.592	.235
Error	35.304	45	.785					
Total	42.000	47						
Corrected Total	36.553	46						

a. R Squared = .034 (Adjusted R Squared = .013)

b. Computed using alpha = .05

Table 10. Univariate Analysis Testing the Relationship between the 1st and 2nd experiment

Tests of Between-Subjects Effects

Dependent Variable: DIFFERENCE_2_C_C

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	10.382[a]	1	10.382	10.319	.002	.187	10.319	.882
Intercept	.425	1	.425	.422	.519	.009	.422	.097
GROUP	10.382	1	10.382	10.319	.002	.187	10.319	.882
Error	45.277	45	1.006					
Total	56.000	47						
Corrected Total	55.660	46						

a. R Squared = .187 (Adjusted R Squared = .168)

b. Computed using alpha = .05

Table 11. Univariate Analysis Testing the Relationship between the 2nd and 3rd experiment

Tests of Between-Subjects Effects								
Dependent Variable: DIFFERENCE_2_C_P								
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	4.535[a]	1	4.535	4.362	.042	.088	4.362	.533
Intercept	17.045	1	17.045	16.395	.000	.267	16.395	.977
GROUP	4.535	1	4.535	4.362	.042	.088	4.362	.533
Error	46.784	45	1.040					
Total	68.000	47						
Corrected Total	51.319	46						

a. R Squared = .088 (Adjusted R Squared = .068)

b. Computed using alpha = .05

Table 12. Univariate Analysis Testing the Relationship between the 2nd and 4th experiment

4.3 Data Analysis of Field Observations

In this section three observations of both the intervention and control group were done, focusing on general observations and perceptions using a student's engagement walkthrough checklist. In the first observation 40% of the intervention group showed high levels of positive mannerisms while in the control group the only observation made was that of low levels of positive mannerisms. Therefore, the intervention group exhibited more positive mannerism. In this same first observation students in both the intervention and control group predominantly showed equal low levels of positive perceptions.

With both groups showing 80% observations of low positive perceptions and 20% of very low positive perceptions., as shown in the diagram below:

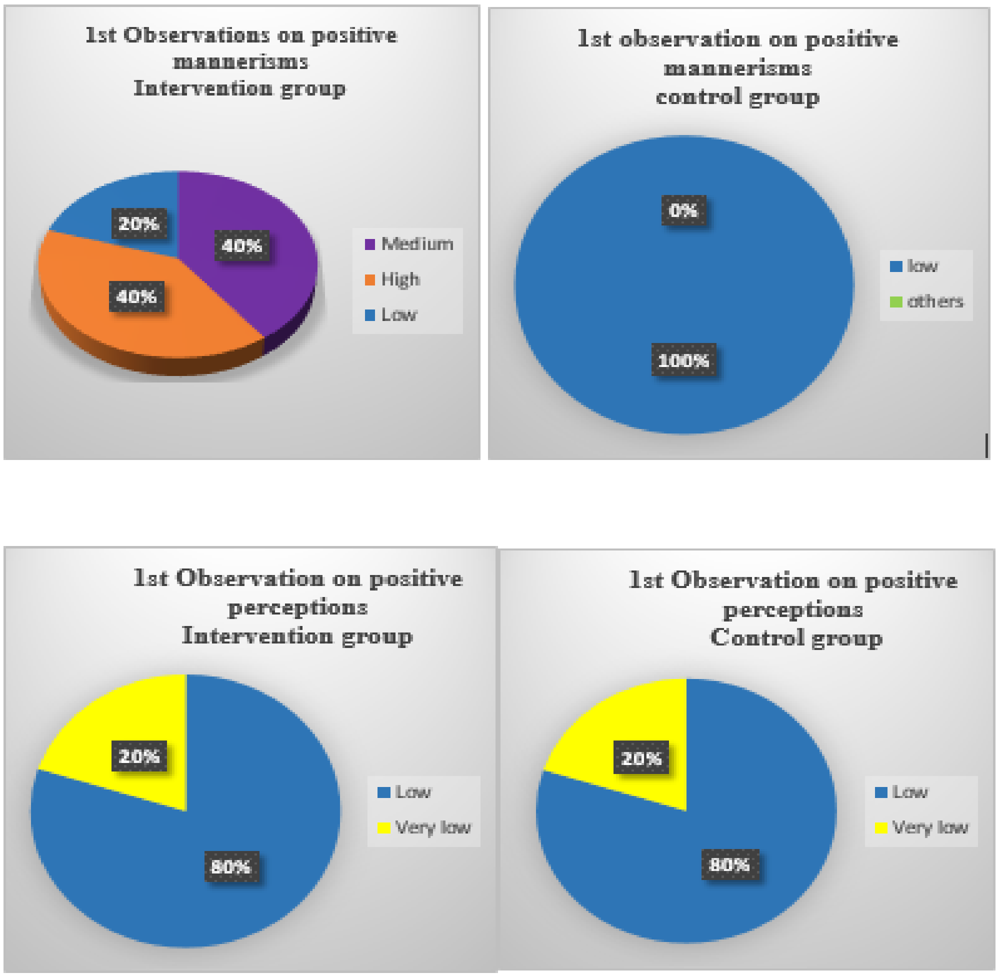


Figure 3. Results from 1st Field Observation

In the second observation there was a 20% increase in the observations of positive mannerism in the intervention group, while 20% of this same group managed to show very high levels of positive mannerisms. In the control group, low positive mannerism still remained as the major observation, although 40% of the students in this group managed to show medium levels of positive mannerisms. When considering positive perceptions, the intervention group has 80%

medium levels and 20% low levels, while the control group showed a score of 20% very low, and 60% low levels of positive mannerisms.

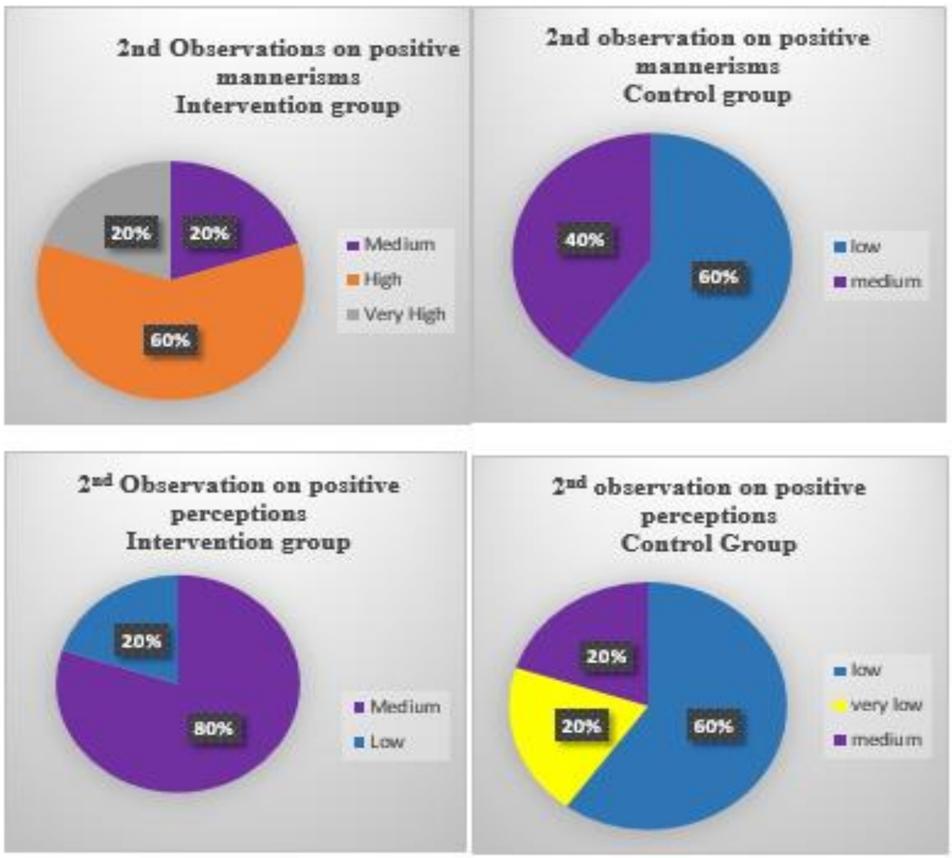


Figure 4. Results from 2nd Field Observation

In the third observation, positive perceptions ranked high in the intervention group at 80%, while the rest of the students in this group were in the medium level of positive perception. Positive mannerisms in this group greatly improved to stand at 60% high levels of positive mannerisms, and 40% very high levels. In the control, observations on positive perceptions and positive mannerisms all ranked at 40% low levels and 40% medium levels.

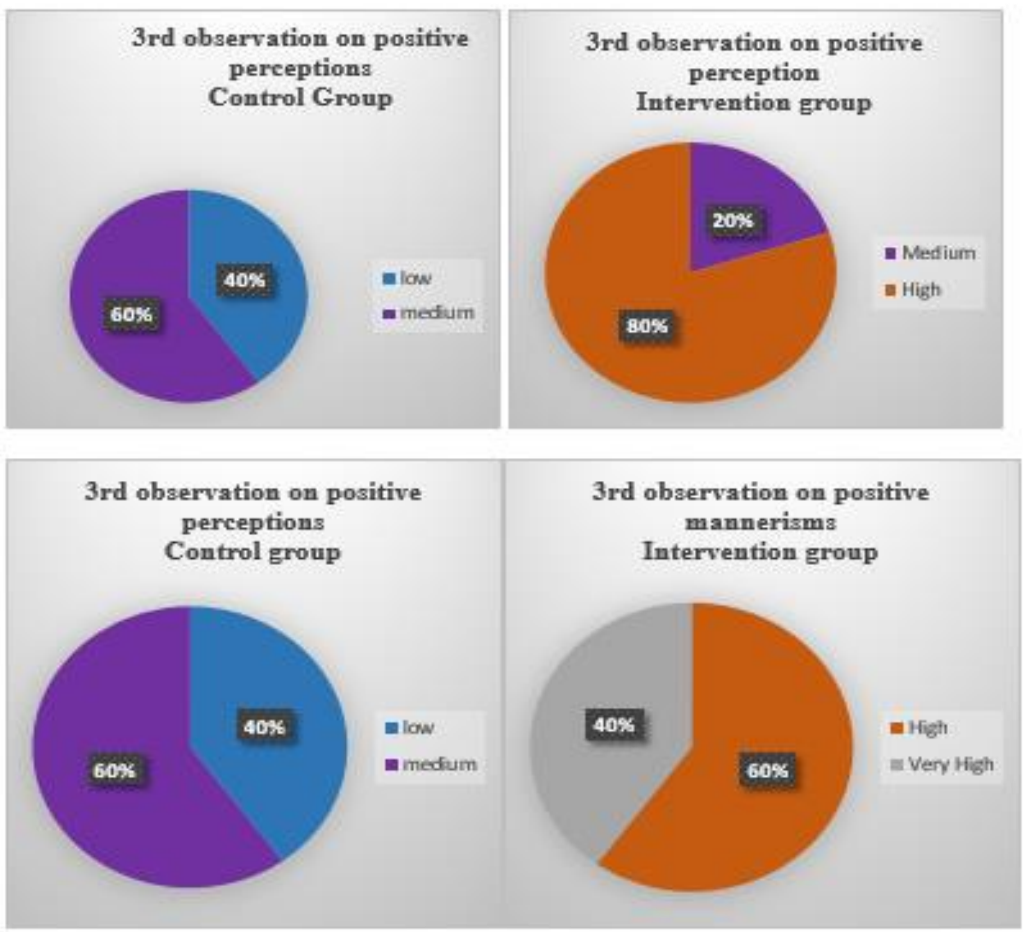


Figure 5. Results from 3rd Field Observation

4.4 Data analysis of Student Survey

The student survey was conducted after the completion of the study and it aimed at gauging the student's attitude, experiences, and perception towards learning science. From the response given by both the intervention and control group it is clear that the intervention group had a better attitude towards science at the end of this study. The bar graph below shows the data pattern from this survey.

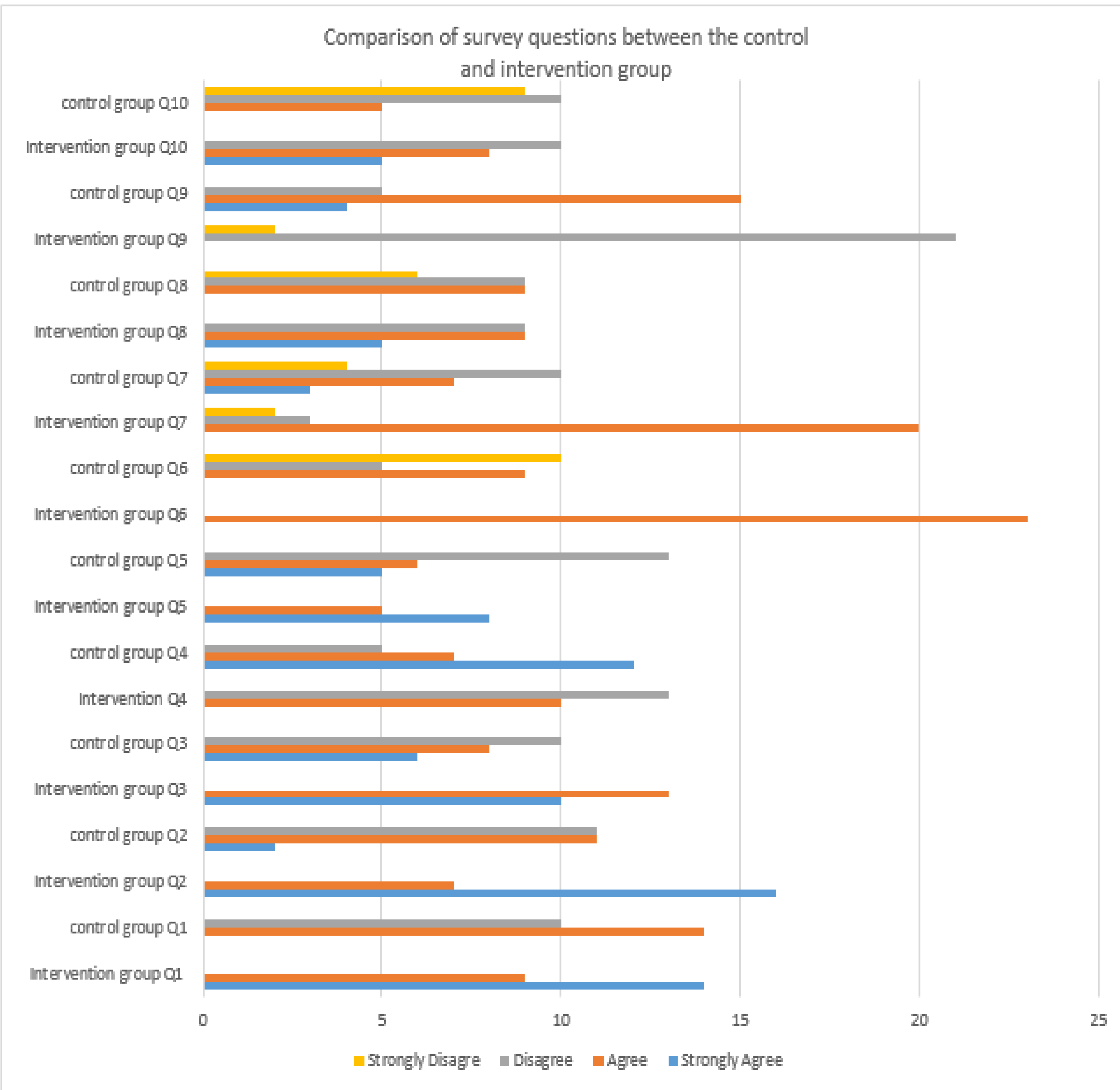


Figure 6. Comparison of Survey Questions between the Control and Intervention Group

Chapter 5: Discussion, Conclusions, and Implications

5.0 Discussion

The aim of this study is to determine if inquiry based learning using laboratory experiments would be effective in improving student's general science laboratory attitudes and achievements. The SPSS analysis of the pre and post-test determined that there was an improvement in student's general science laboratory achievements during the period of the study. To further prove this improvement, statistical significance testing was done and the difference between the pre and post-test was ascertained to be significant ($t = 9.459$; $p < 0.01$). Many researchers have been against the use of statistical significance testing in deciding whether the results of a study are of practical significance. However, in the case of this study, statistical significance testing may have be considered important as we are using a fairly small sample, and hence we have a reduced risk of small non-meaningful differences registering as statistically significant as is the case with large sample.

The results from data analysis also indicated that there was a significant difference between the intervention and the control group in the pre and post-test ($F = 43.240$, $p < 0.01$). The characteristics of the control and intervention groups are uniform, as the Levene's Test of Equality of Error Variances gave a p value of 0.087, hence accepting the null hypothesis that error variance of dependent variable equal in the control and intervention groups. Therefore, it would be safe to say that the implementation of inquiry based learning through laboratory experiments was effective in improving general science laboratory achievements as evidenced by the improvement noticed in the intervention group in the pre and post-test when compared to the control group.

These results concur with other similar studies. In a study done in an Alabama elementary school, the researchers found that inquiry based instructions were more effective in improving mathematics and science scores of fifth graders when compared to the more common teacher directed outcomes. In another study, Vera Septi Andrini found that an inquiry learning approach resulted in improved student's learning outcomes, as opposed to using other learning models that are usually prone to challenges such as monotony, lack of motivation, burnout and boredom (Andrini 2016, p.38). Lastly, researchers also sought to find out the effect that an inquiry based approach towards laboratory experiments would have in undergraduate physiology student's as opposed to using the traditional step-by-step instructions methods in experiments (Nybo & May, p.76). The study determined that inquiry based learning had the potential to realize more benefits for the student's. Therefore, there is evidence supporting the results reached in this study by considering the pre-post-test data analysis.

In this study, students' achievements in four laboratory work sessions between September 29, and November 22 were also considered. One laboratory experiment was done on September 29, the second experiment was done on October 13, and the last two sessions were done on the same day on November 22. The data analysis compared student achievements between the first and the second experiments, and also between the second and third experiment, and the second and fourth experiment. The reason for choosing this approach was to be able to trace changes in student achievements over time, as opposed to just considering the first experiment and the last experiment. Students' achievement in the second experiment showed a significant improvement when compared to their performance in the first experiment. The same trend was observed in the relationship between the second and third experiment. However, a comparison between the second and fourth experiment showed no difference in students' achievements. A univariate analysis with the differences between the experiments serving as the dependent variable showed that the intervention group had a significant improvement over the control group in the two scenarios where an improvement was observed, while no difference between the control and intervention group was noted when comparing the second experiment to the fourth experiment. Despite this lack of improvement in one scenario, the other evidences in this section support the idea that the intervention group should an improvement in achievements as one moved from one laboratory experiment to the next, hence suggesting that inquiry based learning is an effective learning technique for science laboratory achievements. A study that allows the student's to be taught using this approach for a longer period of time may help reduce the uncertainty created by the unfavorable outcomes in the fourth experiment.

As stated before the study also aimed at identifying the student's attitudes towards general science laboratory, and three field observation were done concurrently with the laboratory work sessions to determine how inquiry based learning would affect this attitude. The research focused on two broad categories in this part. The first category is observed positive mannerisms such as a positive body language, consistent focus, fun and excitement, student confidence, and verbal confidence. The second category focused on positive perceptions, where factors such as individual attention, performance orientation, rigorous thinking, clarity of learning, and meaningfulness of work were considered. Considering the data obtained through the student engagement walkthrough checklist, those in the intervention group had better outcomes in both categories that were considered. One can see a gradual increase in the number of students in the intervention group who rank favorably in the checklist, while in the control group the student either have a low rank or a medium rank at most. The results indicate that inquiry based learning can help improve student's attitudes and perceptions towards learning science. This result complements the existing literatures that have also shown this causality effect between these two variables. In a study done in the rural areas of Malaysia, the researchers focused on inquiry based instructions and student's attitudes and how they would affect science achievement. This study showed that inquiry based learning helps students to create a positive attitude towards science which in turn motivates them to engage in science learning hence resulting in better academic achievements (Veloo, Perumal & Vikneswary, p.68). These findings may help explain why the laboratory work achievements and post-test were significantly higher in the intervention group, which has managed to develop a positive attitude towards general science, as opposed to the control group. Before the closure of the study, participating students were given a 10 items survey that aimed at further looking at the student's perceptions and attitudes towards science. The survey also tried to find out how many students thought science would be beneficial to them later in life. The results obtained in this section was the same as the results observed from the field observations where the control showed a negative attitude towards science while the intervention had a positive and better attitude towards the same.

5.1 Implications of the Study

The first implication of this study is that it may necessitate the changing of curriculum standards. As it currently stands, most curriculum standards do not support inquiry based learning but instead they focus on other models of learning such as outcome based learning. Most teachers are usually under pressure to achieve certain outcomes and cover course material within specified times, and this situation would explain the prevalence of the outcome based model of learning. To realize better outcomes in student's and reduce the anxiety and burden shelved by most teachers it might be necessary to overhaul curriculum standards to in favor of standards based on inquiry based learning. Additionally, a research by Sherill Villaluza also identified some disadvantages that may be associated with outcome based learning such as a high investment in time and resources in redundant activities that may be considered wasteful (Villaluza 2017, p.228). Therefore, a clear understanding of inquiry based learning in general science laboratory may result in a change in curriculum standards.

The second implication is that there may be a need for this study to be replicated at a larger scale. Identification of the benefits of inquiry based learning in general science laboratory achievements will only be beneficial if students outside the sample get to benefit from this model. While it may be easy to implement the findings of this study at an organizational level, the same implementation becomes complex when we consider larger settings such as a District. Therefore, a similar study using a larger sample may be necessary to determine if the same benefits can be observed if the model is implemented in a larger more diverse setting.

The third implication affects the teaching practice positively, where instructors or teachers may identify new ways in which to easily motivate students and increase their inclusion in the learning process. Such a scenario not only helps the student to get better academic achievements but it also helps the teachers reduce the burden and stress associated with outcome based learning.

The fourth implication affects how schools record qualitative information from their students. Issues relating to education are complex and need quantitative as well as qualitative consideration. In the great schema of things, it is implied that policies should provide consideration for psychosocial issues surrounding improving students' holistic achievements (Lovelace & Brickman, 2013, p.610). Therefore, there has to be provisions during the term that facilitate the collection of students' perceptions and attitudes towards the learning process.

5.2 Limitations

This study had a few limitations. The first limitation of this study is the fact that there was no random assignment of participants into either the control or intervention group. The fact that the research had to be conducted on normal school schedule made it difficult to randomize the subjects and hence the decision to use participants from one class as the intervention group, and participants from the other class as the control group. However I appreciate the point that lack of randomization may make it impossible to replicate the results from this study in other studies.

The other limitation was the point that mixed methods research methodology is a labor intensive process because it involves carrying out quantitative and qualitative analysis simultaneously and only one researcher was conducting the whole study. It was a very laborious process because of distributing questionnaires, conducting interviews, carrying out field observations, grading pretest and posttest and the subsequent data analysis. The research was also time consuming because one researcher had to oversee and analyze all the processes involved in the research.

The Hawthorne effect was another limitation because students were aware of the point that they were participants in a research. As such, a number of them may have reacted to being observed by modifying their behavior. Behavior modification can lead to the collection of misinformed qualitative data such as data collected from observing the participants.

The size of the sample population was another limitation. The school where research was conducted had classes with less than thirty students per class. As such, one had to work with a limited sample size in the control group and the intervention group. As such, the data collected for research purposes was limited. Consequently, the results were limited in terms of precision and power.

5.3 Recommendations

Other studies with similar sample populations can be conducted in order to check the reliability of the data collected during the study. It is vital for research findings to be directly compared to other research findings. Direct comparisons give a clear picture of the implications of research on practical matters on regional, national or international basis.

The education sector in the UAE can be studied to investigate what percentage of educators have the skills to implement inquiry based learning. It is important for educators to have skills that will enable them teach using IBL. The traditional manner of teaching applies different principles compared to IBL. As such, there should be initiatives to train educators without knowledge on using IBL to teach.

Other investigations can explore the topic further back to investigate the emphasis placed on inquiry based learning when educators are being trained in institutions like colleges and universities. If the emphasis is minimal during training, measures can be placed within the systems of the training centers so that highly skilled educators are sent out into the field.

There is also room to investigate factors that behave in a complementary manner in terms of supporting inquiry based learning in improving the performance and attitudes towards science and other subjects taught in school. Learning cannot be influenced by a single factor only, as such, it is important to conduct research on what other factors can be tailored and used to enhance holistic improvement in learning along the application of IBL.

5.4 Conclusion

Most students consider sciences as difficult subjects and this perception can be attributed to the learning models used in teaching sciences. Inquiry based learning is considered an effective model of learning as it is student centered and it student centered, and the students are actively involved in the learning process, where they can satisfy their curiosity and learn at the same time by asking questions. General science laboratory experiments are a good way of testing the theories learnt in class, although most students fear these experiments and consider them difficult. This research focused on implementing inquiry based learning through laboratory experiments and testing for improvements in achievements and attitudes of science students in general science laboratory experiments. Inquiry based learning in laboratory experiments resulted in increased achievements and improved attitudes which were determined by comparing the control and the intervention groups. The findings from this research can have some implications on the curriculum standards where there may be a need to shift from the more common outcome based approach to the more effective inquiry based learning model. Further implications will be on the need for similar future research using a larger sample to determine its suitability for large scale adoption, and lastly, it may introduce some improvement in the teaching practice.

Figure 7. Differences of the means in the control and intervention groups in both the pretest and the posttest

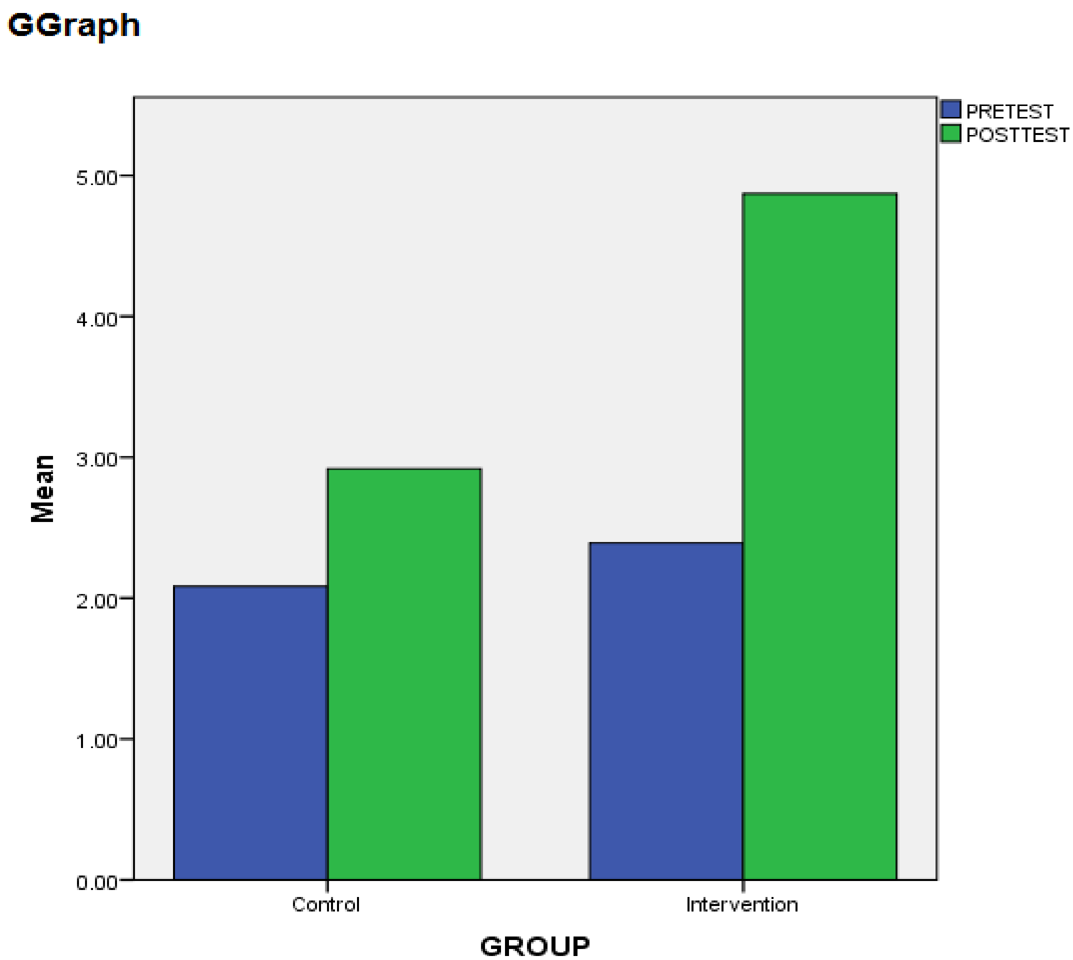
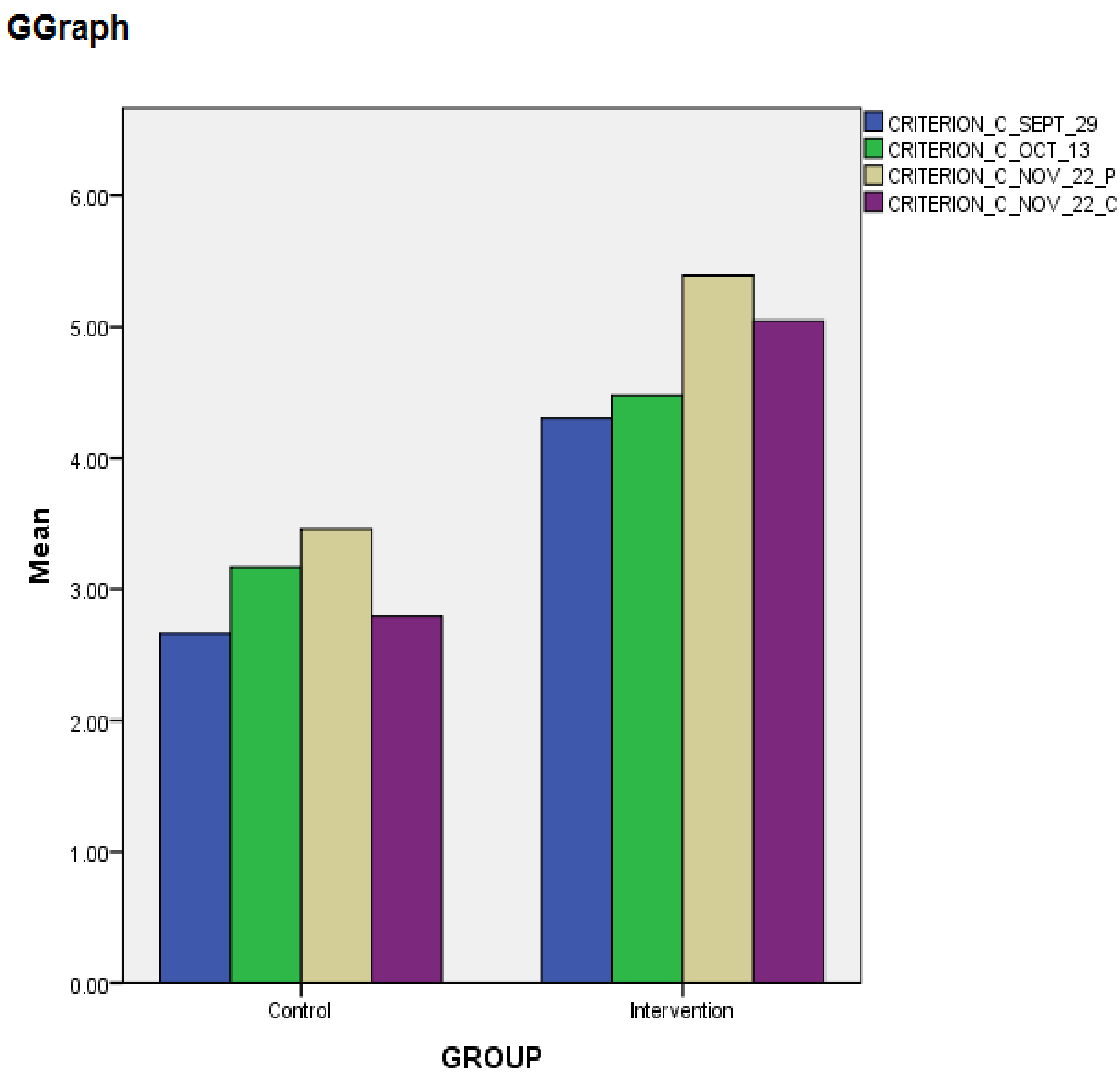


Figure 8. Differences in Achievement in the Four Laboratory Work Sessions



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Appendices

Appendix 1. Pre and Post-Test

Science Assessment – Grade 6

Name: ---------------------------------- Class: ----- Date: -------------------------

Multiple Choice
Identify the choice that best completes the statement or answers the question. Write the letter of the correct answer in the space provided.

Use the following information to answer question 1.
Fatima discovered that a piece of bread left in a sandwich bag had developed a black mold-like substance growing on its surface. She decided to perform an experiment to determine factors affecting mold growth.

____ 1. In Fatima's bread mold experiment, she used the same brand of bread and sandwich bags. She placed the sealed bags in places that had varying temperatures. Temperature is the:
a. control variable.
b. hypothesis.
c. analysis.
d. experimental variable.

____ 2. Which of the following is the same measurement as 2000 grams of soda?
a. 0.2 liters of soda
b. 2 liters of soda
c. 2 kilograms of soda
d. 2 milliliters of soda

____ 3. All matter consists of tiny particles known as atoms. The different types of atoms are known as:
a. elements.
b. compounds.
c. molecules.
d. chemicals.

____ 4. The atoms in gases:
a. vibrate in place.
b. move freely about
c. vibrate and move freely about.
d. vibrate and move freely about, but not at the same time.

Choose the one response below that appropriate fills in the blanks from top to bottom.

_____ 5. Heat is transferred in conduction by_______________.
Heat is transferred in convection by ______________.
Heat is transferred in radiation by ________________.

a. Movement of fluids
Direct contact
Waves through the air

b. waves through the air
direct contact
movement of fluids

c. direct contact
waves through the air
movement of fluids

d. direct contact
movement of fluids
waves through the air

_____ 6. Most of Earth's water is found in which phase?
a. Solid
b. Liquid
c. Gas
d. None of the above

_____ 7. Which of the following is an example of water changing its phase?
a. Glacier ice melting
b. A mud puddle evaporating
c. Dew drops on grass in early morning
d. All of the above

_____ 8. The long-term record of precipitation, wind, and temperature for an area is:
a. weather.
b. climate.
c. meteorology.
d. seasons.

_____ 9. If sustainable energy sources are not found and society continues to primarily use non-renewable energy
a. pollution will decrease
b. there will be an energy shortage
c. there will be more jobs created
d. people will stop needing energy

_____ 10. If humans put too much pollution in the environment:
a. plants and animals can die.
b. habitats can be destroyed.
c. animals move to cleaner areas.
d. all of the above.

_____ 11. An astronaut weighs 400 Newtons on the Moon's surface. On Earth they would:
a. weigh less.
b. weigh more
c. weigh the same
d. increase in mass

_____ 12. Which of the following is most responsible for causing changing seasons on Earth each year?
a. Closeness to Earth to Sun during orbit
b. Speed of Earth's rotation
c. Tilt of Earth on its axis
d. Amount of meteorites in sky

_____ 13. During which phase of the Moon does a solar eclipse occur?
a. Full Moon
b. New Moon
c. Waning Gibbous
d. First Quarter

_____ 14. Buoyancy describes the concept that:
a. all objects float in water
b. objects denser than water will float in it
c. less dense objects will float in more dense fluids
d. objects must be filled with air in order to float

_____ 15. The state of water as a solid, liquid, or gas in the water cycle is most affected by:
a. humidity
b. wind
c. amount of water
d. temperature

_____ 16. Water and ketchup are each poured onto a tray from two separate bottles. The charts below represent the amount of time it takes each liquid to flow from the top to the bottom of the tray.

Water Data

Trial #	Time (sec.)
1	2
2	3
3	2

Ketchup Data

Trial #	Time (sec.)
1	35
2	35
3	40

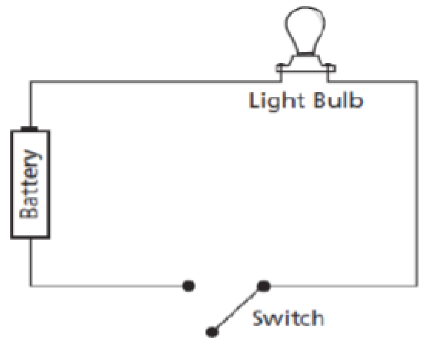
What conclusion is best supported by the data?
a. Thicker liquids take longer to travel to the bottom of a tray.
b. Thicker liquids take less time to travel to the bottom of a tray.
c. Liquid with sugar crystals travels to the bottom of a tray faster.
d. Liquid with a darker color travels to the bottom of a tray faster.

_____ 17. When an object's volume is made smaller and its mass remains the same, its density
a. increases.
b. decreases.
c. remains the same.
d. increases then decreases.

_____ 18. Which set of objects best conducts electricity?
a. an iron washer and a metal fork
b. a door key and a rubber ball
c. a copper pipe and a wooden spoon
d. a rubber mallet and a glass measuring cup

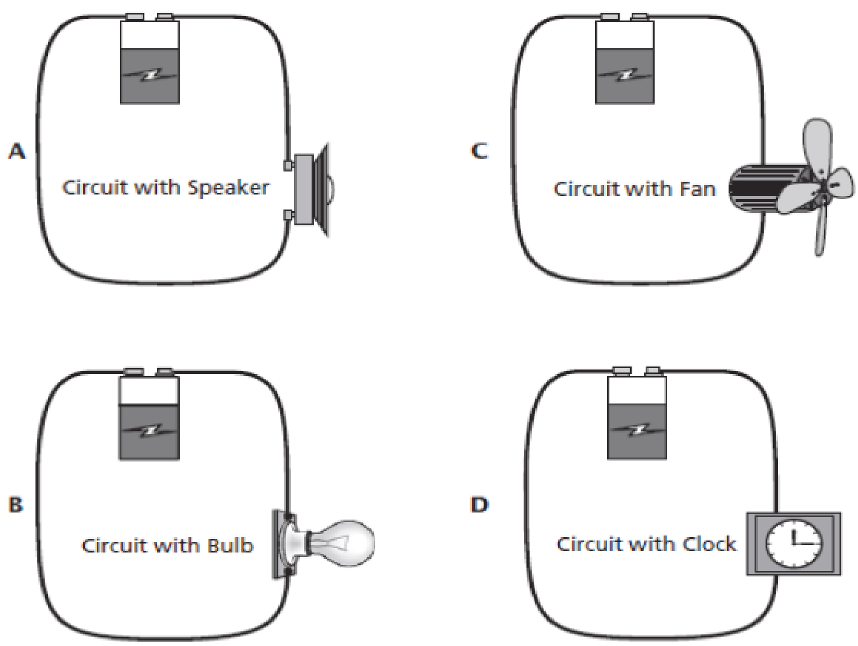
_____ 19. An object moves rapidly as it is thrown upward. Its motion slows as it reaches a maximum height, and then it falls back down. What causes the upward motion to become slower?
a. The kinetic energy is converted to wind energy.
b. The kinetic energy is converted to gravitational potential energy.
c. The gravitational potential energy is converted to kinetic energy.
d. The gravitational potential energy is converted to light energy.

____ 20. The diagram below shows a simple electrical circuit.

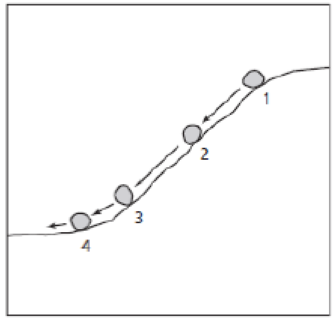


What energy conversions occur when the switch is closed?
a. chemical energy → electrical energy → light energy
b. light energy → electrical energy → thermal energy
c. thermal energy → electrical energy → light energy
d. light energy → chemical energy → electrical energy

____ 21. Which simple circuit most likely produces heat and light energy?



_____ 22. The illustration below shows the locations of a rock as it rolls down a slope.



Which location best shows the rock with the greatest kinetic energy and the least potential energy?
a. 1
b. 2
c. 3
d. 4

_____ 23. A rubber band is stretched between a person's fingers and then released. This best demonstrates
a. products and reactants.
b. friction and air resistance.
c. physical and chemical changes.
d. potential and kinetic energy.

_____ 24. Which type of energy is converted when fireworks release heat, light, and sound?
a. kinetic energy
b. elastic potential energy
c. chemical potential energy
d. electromagnetic energy

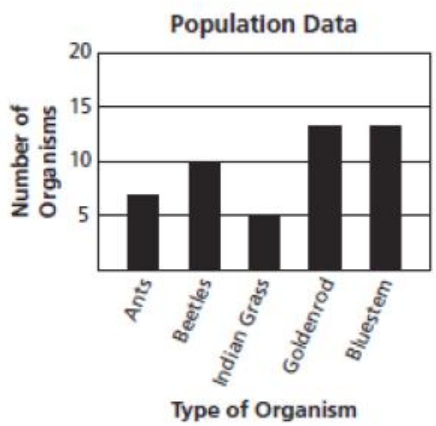
_____ 25. Which type of energy is being converted into kinetic energy as a marble falls from a shelf?
a. electrical potential energy
b. gravitational potential energy
c. elastic potential energy
d. chemical potential energy

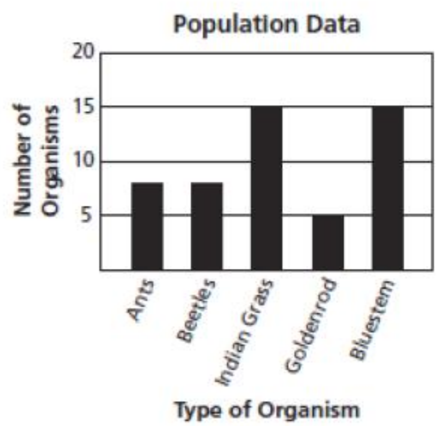
____ 26. Students counted the number of organisms located in a one-meter square plot in a grassland prairie. Their data are shown below.

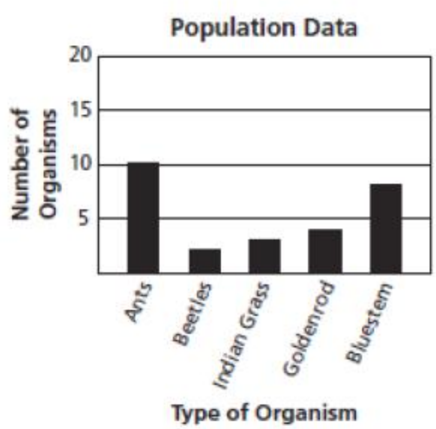
Population Data

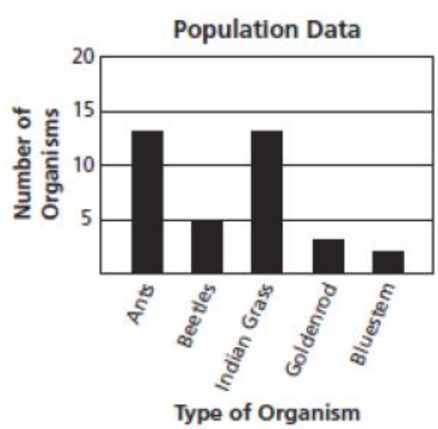
Organism	Number of Organisms
Ants	10
Beetles	2
Indian Grass	3
Goldenrod	4
Bluestem	8

Which graph best represents the data?

A


C


B


D


_____ 27. Sarah has 100 g of each element listed in the chart below, which also provides the melting point for each element.

Melting Point for Elements

Element	Melting Point
copper	1,084°C
gold	1,064°C
lead	327°C
silver	961°C

What would happen if she melted only 50 g of each element?
a. The melting point for each element would double because the mass was changed.
b. The melting point for each element would decrease by half because the mass was changed.
c. The melting process would occur more quickly, but the melting points would remain the same.
d. The melting process would occur more quickly, but the melting points would be decreased by half.

_____ 28. Why are some coffee cups composed of ceramic material?
a. Ceramic materials are conductors that limit heat transfer.
b. Ceramic materials are insulators that limit heat transfer.
c. Ceramic materials are conductors that aid heat transfer.
d. Ceramic materials are insulators that aid heat transfer.

This is the end of the multiple-choice portion of the test.

Short Answer

29. Energy can be transferred from one object to another.
□ a) How is heat energy transferred by conduction?

____

____

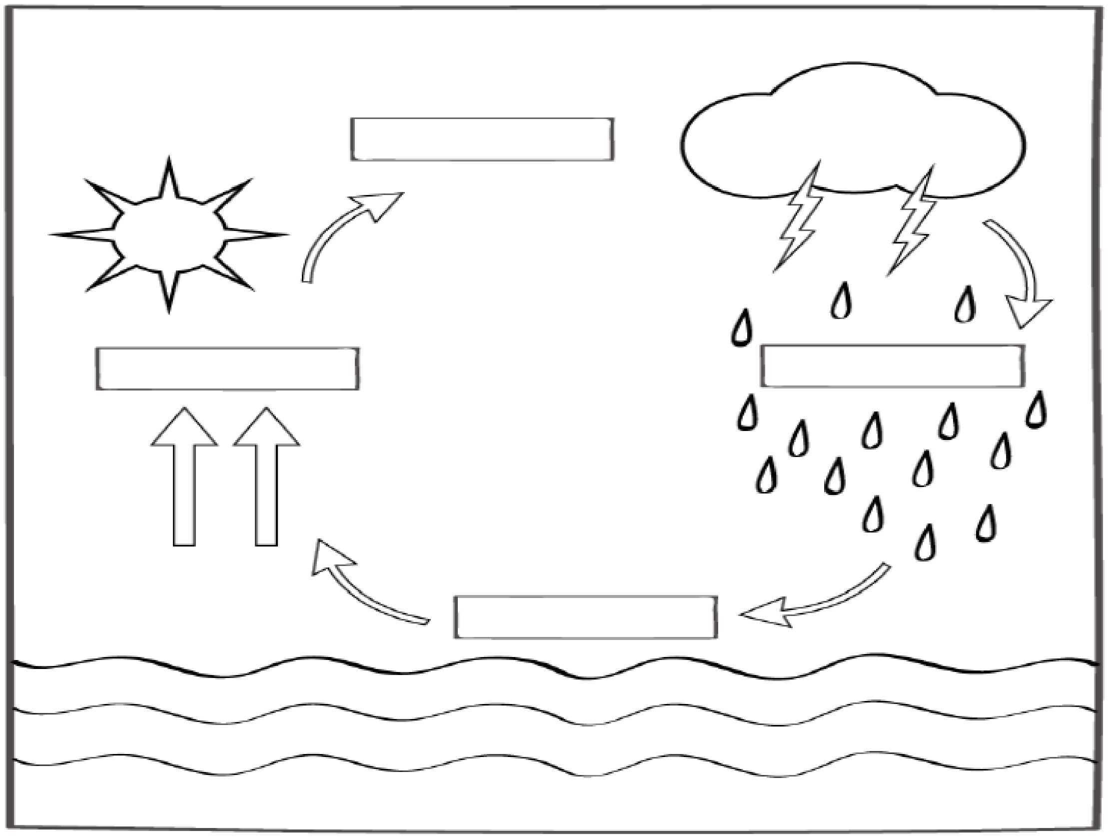
b) Provide an example of how heat is transferred by conduction.

____

____

30 – a) Label the picture below that illustrates the water cycle. Use the words are provided.

Collection - Evaporation - Precipitation - Condensation



b) Trace the path of water from the ocean to groundwater and back to the ocean. Describe the processes that allow water to travel from the ocean to the groundwater.

____

____

____

____

____

Appendix 2. Rubric of Criterion A: Knowing and Understanding

<u>Criterion A:</u> Knowing and understanding

i. outline scientific knowledge
ii. apply scientific knowledge and understanding to solve problems set in familiar situations and suggest solutions to problems set in unfamiliar situations
iii. interpret information to make scientifically supported judgments.

Achievement level	Level descriptor	Questions
0	The student **does not** reach a standard described by any of the descriptors below.	
1-2	The student is able to: **i.** **select** scientific knowledge	3
1-2	**ii.** **select** scientific knowledge and understanding to **suggest solutions** to problems set in **familiar situations**	1,29a
1-2	**iii.** **apply** information to **make judgments, with limited success.**	6,29b
3-4	The student is able to: **i.** **recall** scientific knowledge	4,8
3-4	**ii.** **apply** scientific knowledge and understanding to **suggest solutions** to problems set in **familiar situations**	24,26
3-4	**iii.** **apply** information to **make judgments.**	2,7,25
5-6	The student is able to: **i.** **state** scientific knowledge	5,21,30a

5-6	**ii.** **apply** scientific knowledge and understanding to **solve problems** set in **familiar situations**	9,10,20
5-6	**iii.** **apply** information to **make scientifically supported judgments.**	15,19,28
7-8	The student is able to: **i.** **outline** scientific knowledge	12,13,14,18
7-8	**ii.** **apply** scientific knowledge and understanding to **solve problems** set in **familiar situations** and **suggest solutions** to problems set in **unfamiliar situations**	11,23,27
7-8	**iii.** **interpret** information to **make scientifically supported judgments.**	16,17,22,30b

Appendix 3. Rubric of Criterion C: Processing and Evaluating

<u>Criterion C:</u> Processing and Evaluating

i. present collected and transformed data
ii. interpret data and outline results using scientific reasoning
iii. discuss the validity of a prediction based on the outcome of the scientific investigation
iv. discuss the validity of the method
v. describe improvements or extensions to the method.

Achievement level	Level descriptor
0	The student **does not** reach a standard described by any of the descriptors below.
1-2	The student is able to: i. **collect and present** data in numerical and/or visual forms ii. **interpret** data iii. **state** the validity of a prediction based on the outcome of a scientific investigation, **with limited success** iv. **state** the validity of the method based on the outcome of a scientific investigation, **with limited success** v. **state** improvements or extensions to the method that would benefit the scientific investigation, **with limited success**.
3-4	The student is able to: i. **correctly collect and present** data in numerical and/or visual forms ii. **accurately interpret** data and **outline** results iii. **state** the validity of a prediction based on the outcome of a scientific investigation iv. **state** the validity of the method based on the outcome of a scientific investigation v. **state** improvements or extensions to the method that would benefit the scientific investigation.
5-6	The student is able to: i. **correctly collect, organize and present** data in numerical and/or visual forms ii. **accurately interpret** data and **outline** results **using scientific reasoning** iii. **outline** the validity of a prediction based on the outcome of a scientific investigation

	iv. **outline** the validity of the method based on the outcome of a scientific investigation v. **outline** improvements or extensions to the method that would benefit the scientific investigation.
7-8	The student is able to: i. **correctly collect, organize, transform and present** data in numerical and/ or visual forms ii. **accurately interpret data** and **outline** results **using correct scientific reasoning** iii. **discuss** the validity of a prediction based on the outcome of a scientific investigation iv. **discuss** the validity of the method based on the outcome of a scientific investigation v. **describe** improvements or extensions to the method that would benefit the scientific investigation

Appendix 4: Teacher Field Observations

Student Engagement Walkthrough Checklist

OBSERVATIONS

	Very High	High	Medium	Low	Very Low
Positive Body Language	☐	☐	☐	☐	☐
Students exhibit body postures that indicate they are paying attention to the teacher and/or other students.					
Consistent Focus	☐	☐	☐	☐	☐
All students are focused on the learning activity with minimum disruptions.					
Verbal Participation	☐	☐	☐	☐	☐
Students express thoughtful ideas, reflective answers, and questions relevant or appropriate to learning.					
Student Confidence	☐	☐	☐	☐	☐
Students exhibit confidence and can initiate and complete a task with limited coaching and can work in a group.					
Fun and Excitement	☐	☐	☐	☐	☐
Students exhibit interest and enthusiasm and use positive humor.					

PERCEPTIONS

	Very High	High	Medium	Low	Very Low
Individual Attention	☐	☐	☐	☐	☐
Students feel comfortable seeking help and asking questions.					
Question to Ask: What do you do in this class if you need extra help?					
Clarity of Learning	☐	☐	☐	☐	☐
Students can describe the purpose of the lesson or unit. This is not the same as being able to describe the activity being done during class.					
Questions to Ask: What are you working on? What are you learning from this work?					
Meaningfulness of Work	☐	☐	☐	☐	☐
Students find the work interesting, challenging, and connected to learning.					
Questions to Ask: What are you learning? Is this work interesting to you? Do you know why you are learning this?					
Rigorous Thinking	☐	☐	☐	☐	☐
Students work on complex problems, create original solutions, and reflect on the quality of their work.					
Questions to Ask: How challenging is this work? In what ways do you have the opportunity to be creative?					
Performance Orientation	☐	☐	☐	☐	☐
Students understand what quality work is and how it will be assessed. They also can describe the criteria by which their work will be evaluated.					
Questions to Ask: How do you know you have done good work? What are some elements of quality work?					

Overall Level of Student Engagement	☐	☐	☐	☐	☐

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Appendix 5: Students Survey

The Question	Strongly Agree	Agree	Disagree	Strongly Disagree
1. I enjoy learning science.				
2. I would like to study science in more detail than I do now.				
3. Science is useful in everyday life.				
4. I worry about failing science tests.				
5. I usually understand what we are doing in science.				
6. I think I could do more difficult science work.				
7. Being a scientist might be fun.				
8. I plan on studying science or engineering in college.				
9. Being in a science class makes me feel stressed or nervous.				
10. I'll need science for my career/future job.				

*LISD Student Interest Survey - Science Motivation