THE EFFECTS OF USING GUIDED INQUIRY WITH TECHNOLOGY, INCLUDING
SIMULATIONS AND VIRTUAL LABS, ON STUDENT UNDERSTANDING OF
CONCEPTS IN ADVANCED PLACEMENT PHYSICS CLASSES

by

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STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master’s degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

Jayanthi Ramakrishna

July 2013
DEDICATION

This is dedicated to my beloved husband, Ramakrishna whose continuous support and encouraging words have motivated me to do my best.
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This study investigated the effects of using guided inquiry with technology, including simulations and virtual labs on student understanding of concepts in an Advanced Placement Physics Class. The students used simulations and virtual labs to learn concepts in electricity such as Kirchhoff’s laws and electrostatics. The data collection instruments included pre and postunit assessments, surveys, concept interviews, self-evaluation, and observation by a colleague to determine the effects of using guided inquiry with technology in the understanding and long-term memory of physics concepts, students’ interest, attitude and motivation, and attitude of the teacher. There was an increase in students’ interest and motivation and also an increased enthusiasm and positive outlook on the part of the teacher after the treatment. The study of the effect of the treatments on concept understanding and long-term memory produced mixed results and was inconclusive.
INTRODUCTION AND BACKGROUND

My experience as a high school physics teacher has taught me to be unbiased, and to accept changes in the field of education for the best interests of my students. I have used various strategies ranging from differentiating instruction for language learners to providing enriched learning for gifted students. Technology in the 21st century, and its impact on learning science, appears to be a top priority in most schools. In the early days of using technology, I did have apprehensions about its misuse since all resources on the Internet are not necessarily authentic. Physics is a pure science, understanding of which requires the imagination to visualize abstract concepts. I have tried a range of methods to impart knowledge by lecture, repetitions, worksheets, and formative assessments that include individual and group projects and class activities. In all these years of teaching, I have observed that the learning is short-term and is usually confined to the performance done soon after the lesson. There should be a vivid understanding of concepts with the realization that these are applicable to real life situations and that nature is governed by laws of physics. The physicist is only trying to find answers to the mysteries that already exist in the universe. In recent times I have experimented with teaching physics concepts through computer guided visual learning and the results look promising. Visual learning through simulations and virtual labs, supplemented with a guided inquiry, appear to help students understand the concepts better and also enable its long-term memory. It is often a challenge to teach the entire curriculum within a time frame in a higher level physics class, and prepare them for exams like the Advanced Placement. I have noticed that my students master a skill or lesson in half the time by using technology in guided inquiry lessons. Also, technology is dynamic and provides educators with the opportunity of
using appropriate tools in teaching physics. Learning styles may vary from visual to
textual but even textual learners are benefited when the model is visual. Using computer
simulations and virtual labs with hands on activities keep students interested in science.

My school is an international school in India that follows the American
curriculum and is managed by the American Consulate in India. Students are
international, coming from a range of nationalities, and constantly changing. The school
offers both the International Baccalaureate diploma program as well as the Advanced Placement® (AP) programs for a variety of subjects. The English as a Second Language (ESL) department in the school plays a major role in helping students learn the language and join the mainstream classes. I have based my study on students in the AP Physics class.

Low motivation can hinder optimal student learning in several ways (Pearce, 2007). The textual learning and traditional lecture methods are often dry and not attractive. As a physics teacher, the difficulty for me has always been to teach students all topics within the stipulated time and to do so effectively. My small pilot study using guided inquiry with technology encouraged me to conduct the entire study as a part of my project. I have made a thorough study of my project questions about using guided inquiry with the use of technology, and then shared the results with fellow teachers, administrators, and parents.

My focus question is: What are the effects of using guided inquiry with technology, including simulations and virtual labs, on student understanding of concepts in high school AP Physics classes? My project subquestions are: what are the effects of using guided inquiry with technology on students' long-term memory of physics
concepts; what are the effects of using guided inquiry with technology on students’ interest and motivation; and what are the effects of using guided inquiry with technology on my teaching, and attitudes to teaching?

Guided inquiry is a method of inquiry-based learning where the students are given a research question and they have to design, make a procedure, test the validity of their design, obtain results, and explain them. Guidance is not structured. It is a way of exploration with occasional guidance which could be in the form of probing questions or inquiry questions handouts.

My project advisor was Dr. Jewel Reuter who has guided me good-naturedly before, during, and after my research. My MSU reader was Mr. Richie Boyd, the Academic technology specialist at the Montana State University. My support group comprise of Mrs. Kala Ganeshan who is a colleague and Head of the Mathematics department in my school and a former colleague Mrs. Vasantha Prasad who was a chemistry teacher in the school. Mrs. Ganeshan has a Master of Science degree in Physics from an Indian university and the Master of Science in Mathematics education from the University of New Jersey, and Mrs. Vasantha Prasad has a Master of Science degree in Biology from an Indian university and the Master of Science in Science Education degree from Montana State University. They have patiently read my paper and given me valuable feedback during the research and writing. Mrs. Ganeshan has also observed my lessons during the treatments and given me suggestions and input.
CONCEPTUAL FRAMEWORK

The conceptual framework includes the literature reviewed on technology-guided teaching of physics concepts. I used a constructivist approach to the learning of physics concepts where inquiry is guided with open-ended questions and the appropriate use of technology such as simulations and virtual labs. The inquiry-based model that I have used is based on the ideals and principles of constructivism.

Constructivism is a theory about how we come to know what we know. It is founded on the premise that children, adolescents, and even adults construct or make meaning about the world around them based on the context of their existing knowledge. This is done by reflecting on our prior experiences (Mintzes, 1998). Meaning-making strategies is the fundamental adaptation of the human species and the driving force underlying all forms of conceptual change, whether that change occurs in the mind of the experienced professional scientist or a young child confronting the wonders of nature for the first time (Mintzes, 1998).

Novak (1993) summarized his belief that from birth to senescence or death, individuals construct and reconstruct the meaning of events and objects they observe. For the constructivist, knowledge is created rather than discovered. Even those who have been critical of the constructivist stance have acknowledged its success in generating a significant body of empirical data. This has contributed to our knowledge and understanding of difficulties in the learning of science; enabling the development of some innovative teaching methods and creating a greater awareness of the central importance of the learner (Kinchin, 1998; Osborne, 1996).
Studies reported in the literature describe the advantages of a constructivist approach to teaching biology, including improvements to test results, student attitudes, and student enjoyment of the subject (Lord, 1997).

Constructivism emphasizes that science is a creative human endeavor which is historically and culturally conditioned and that its knowledge claims are not absolute. In the first stage of the process of conceptual change, which can also be seen as a process of construction of shared meanings between the student and the teacher, it is important for both the student and teacher to identify misconceptions within naïve theories as a preparation for further learning. This must be done so that they do not impede meaningful learning (learning which is built upon existing understanding in the constructivist tradition (Bay, 2000). Some of the key assertions made by Mintzes and Wandersee (1998) in their discussion of the Theory of Human Constructivism, are that human beings are meaning makers, the goal of education is the construction of shared meanings, and shared meanings may be facilitated by the active intervention of well-prepared teachers.

The research in constructivism in this century has identified technology to be a good tool to assist inquiry. Computers provide the technological capacity needed to collect and interpret information about the natural world that is not limited by the five senses. For example, the concept of current and electron flow appeals more to the student while watching an animation showing the same. The underlying assumption is that using computer animations during classroom instruction allows students to visualize an abstract concept that might otherwise be inaccessible using traditional teaching methods, such as reading a textbook, viewing a diagram, or hearing a teacher-delivered lecture (Klenk, 2011). The concepts in electrostatics and magnetism units are often abstract and students
find it difficult to understand them well. It helps student learn when the teacher, therefore, uses both visual and textual methods to teach these topics. The Physics Education Technology Project (PhET) launched by the University of Colorado has a plethora of simulations that not only serve as an animation of the concept but also provide for changing the variables, and thus are virtual labs.

Vick (2010) in his article that describes the experience of using the PhET Circuit Construction kit for understanding electric circuits through virtual labs by 11th and 12th-grade physics students, mentions that the PhET simulations help students visualize the invisible world of electrons and address the misconception that electrons are used up in a circuit. These simulations provide a means of virtual data collection. Students analyze the data and understand the concept of electron flow in a conductor. The simulations by themselves do not make for a constructivist, inquiry-based lesson. The teacher must use these simulations as a tool for exploration and discussion. Lee (2012) did research concerning computer simulations to facilitate conceptual understanding of electromagnetic induction and he says that the research-based approaches to integrated computer simulations in physics education form a learning framework called Concept Learning with Computer Simulations (CLCS). A component of his study was to examine the CLCS learning framework empirically. The participants were recruited from a public high school in Beijing, China. All participating students were randomly assigned to two groups, the experimental (CLCS) group and the control traditional group (TRAD) group. The result suggested that more TRAD students knew what kinds of conditions may or may not cause electromagnetic induction without understanding how electromagnetic
induction works. (Lee, 2012). They understood what the conditions for electromagnetic induction are, but not the concept of electromagnetic induction.

The CLCS learning framework revealed some limitations to promote conceptual understanding in physics. It suggested that improvement could be made by providing students with background knowledge necessary to understand model reasoning and incorporating the CLCS learning framework with other learning frameworks to promote integration of various physics concepts. In addition, the reflective questions in the CLCS learning framework may be refined to better address students' difficulties. This study showed the limitations in both the TRAD and the CLCS model and emphasized the need to address the limitations in the CLCS model.

The introductory freshmen electromagnetism course at MIT (Massachusetts Institute of Technology) using a studio physics format entitled Technology Enabled Active Learning (TEAL) has been adopted and utilized since 2000. TEAL has created a collaborative, hands-on environment where students carry out desktop experiments, submit web-based assignments, and have access to a host of visualizations and simulations. These learning tools help them visualize unseen electromagnetic concepts and develop stronger intuition about related phenomena. A previous study has shown that students who took the course in the TEAL format (the experimental group) gained significantly better conceptual understanding than those who took it in the traditional lecture-recitation format (the control group). The longitudinal study explained here focuses on the extent to which these two research groups (experimental and control) retain conceptual understanding about a year to 18 months after finishing the course. It also examines students’ attitudes about whether the teaching format (TEAL or
traditional) contributes to their learning in advanced courses. The visualizations support meaningful learning by enabling the presentation of spatial and dynamic images that portray relationships. The research has indicated that the long-term effect of the TEAL course on students’ retention of concepts was significantly stronger than that of the traditional course. This research is significant because it documents the long-term cognitive and affective impact of the TEAL studio physics format on learning outcomes (Dori, 2007).

With respect to student attitudes, Sims (2012) did a study where he gauged students’ attitudes towards computer use in lab settings in first year secondary chemistry classes. This was accomplished through measuring student attitudes on the usefulness of computers, and anxiety towards computers. Students’ attitudes towards computer use in lab settings were favorable. About 73% of students believed that computers were useful in lab settings and 64% had little or no anxiety towards the use of computers in laboratory settings. These findings suggest that, in terms of an instructional medium for lab experiences, students showed preference towards the inclusion of computers in lab settings. The use of technology has fundamentally changed the pedagogical practices of the classroom.

Technology integration refers to the practice of incorporating technology in teaching (Koehler & Mishra, 2008). Beichner et al. (1999) reported that high school science students taught with a technology-rich, collaborative, activity-based instructional approach outperformed those who studied with the traditional teaching method. They also found that students’ satisfaction, confidence, and retention rates were noticeably high. Hake (2007) asserted that although high-tech alone does not ensure superior student
learning, it can be beneficial when it comes to promoting interactive-engagement. Several studies have specifically examined the impact of TEAL on university students studying introductory physics courses and found that students exposed to TEAL achieved higher learning gains than those studying in traditional classrooms (Sheih, Chang, & Liu, 2010, 2011) and students' retention of concepts was significantly greater (Dori, Hult, Breslow, & Belcher, 2007). According to the interview data, most of the students regarded physics as a difficult subject to study. However, compared to the control students, the TEAL students showed more positive attitudes toward going to the physics class because they said it was fun. They reported that such activities were interesting and helped them to be better able to connect the theory to their real-life experiences.

Several studies (Sheingold & Hadley, 1990; Dwyer et al., 1990) have identified the characteristics and beliefs of teachers who are successful users of technologies. Teaching with technology seems to influence teaching style toward an increasingly student-centered and active learning orientation. At the same time, teachers with progressive beliefs about teaching, tend to be drawn toward using technology. Honey and Moeller (1990) provide additional information about the distinct differences in teachers who use technology and those who do not use technology. In his study of an investigation on the effects of using interactive digital video in the physics classroom on student learning and attitudes Escalada (1995) says that for teachers with a high level of technology, implementation were fairly similar and tended to concentrate on instilling a sense of curiosity and desire to learn in their students. Teachers reduced the amount of time spent on content and devoted more time on inquiry-based approaches which helped students develop critical thinking. These teachers use technology within a process-
oriented approach to enable students to reach well-defined curricular objectives. They believed that allowing students to explore and to use computer applications resulted in increased learning since the students enjoyed finding creative ways to master the curriculum. Teachers who are more likely to use scientific inquiry in their classes are the same teachers who are more likely to use technology, in their classes (Escalada, 1995).

Technology supports inquiry-based learning. Students use virtual labs and simulations for visualizing concepts but the concept is learned through inquiry. Technology makes the work simpler by letting students visualize the concepts. It is best when teachers provide continuous guidance in the form of probing and open ended questions, discussions, and clearing of misconceptions.

As teachers are exposed to new ideas and try to put those ideas into practice in the classroom, their belief systems do change, but the new beliefs may not entirely supplant previous beliefs (Yerrick, Parke, & Nugent, 1997). According to the International Society for Technology in Education (ISTE), National Educational Technology Standards (NETS) for Teachers (2008), teachers nowadays are expected to use their knowledge of subject matter, teaching and learning, and technology to facilitate student learning.

**METHODOLOGY**

**Project Treatment**

To assess the outcomes of my intervention, data were collected from nontreatment and two treatment units for comparison. The nontreatment unit was taught with a traditional teacher-centered approach while the treatment units used student-centered guided inquiry labs and classroom activities.
The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Guided inquiry in my class began with a few verbal questions, a handout with inquiry-based open-ended questions and website link or login information to virtual laboratory software. The lesson began with a discussion and probable answers to the prelab questions followed by students working in pairs or in groups. My role was to go to the different groups, pose and answer questions that not only encouraged inquiry but also addressed preconceptions and misconceptions. The project was completed over six weeks with a nontreatment unit and two treatment units that began in January and ended in March. The timeline is attached in Appendix A.

The class duration was 1 hour 30 minutes. In the nontreatment section, I did not use inquiry with technology. I began by asking students about their knowledge of an electric charge. I gave a Know, Want, and Learn (KWL) sheet and got their response. The responses were varied with a few having some understanding of the concept of charge than the others. I activated students' prior knowledge by asking them what they already know; then students (collaborating as a classroom unit or within small groups) set goals specifying what they want to learn; and later students discussed what they have learned.

At the beginning of the nontreatment unit, students were introduced to Ohm’s law, concept of voltage, current, resistance, and their dependence on each other. Students were given an open ended inquiry worksheet. The class was a traditional lecture where the physical quantities such voltage, current and resistance were defined and explained.
Students were asked inquiry questions during the course of the lesson. Students were given an imaginary set of data to reinforce the dependence of voltage, current and resistance on one another. They were asked to analyze the data and plot graphs to verify Ohm’s law. The lesson was then extended to draw and analyze circuits in which the resistors were connected in series and parallel. The proofs for the effective resistances in both the types of connections were then explained. Students were given a set of problems involving resistor networks and voltage sources to solve for effective resistance, voltage across resistors, and currents in the various branches. Students were asked to write daily reflections on the lesson in a journal as a part of their homework.

Students` journals provided me with a valuable window into the students` world (in much the same way that homework assignments provide parents with insights into their children`s daily experiences) (Mills, 2011). The nontreatment unit lesson plan is provided in Appendix B.

The treatment unit 1 used inquiry with technology and focused on Kirchhoff`s laws. Students were given an inquiry sheet that had the necessary prompts required for the inquiry. Students were then given the website address for the virtual lab.

The two theorems were introduced by a virtual lab where students were able to explore with different combinations of circuits. The virtual lab illustrated the directions of the current and displayed the voltages across components. Students were able to actually visualize the two laws namely the Junction Theorem that states that the total current entering a junction in an electrical network is equal to the total current leaving the junction and the voltage law that states that the sum of the potential differences across the various components in a closed circuit is equal to the sum of the electromotive forces in
the circuit. This was followed by an animation to understand the conventions in the
directions taken on the loop and about choosing the loops to solve problems correctly.
Students were then expected to do the virtual lab and take and make observations. They
were then guided to complete the data processing and analysis. The final step in the
process is the connection they made between the theory and their guided inquiry with
technology, and, thus, reflect on the concepts and submitted a laboratory report later in
the week. Students completed a teacher guided class work on the application of
Kirchhoff’s laws to numerical problems. They were allowed to go back and look at the
simulations and the virtual lab while solving problems. Students wrote reflections about
the lessons daily and maintained a journal. They took a test after the unit. Students were
also expected to complete numerical problems based on the unit. A concept interview
was conducted after the treatment. A sample lesson plan for treatment unit 1 is given in
Appendix D. The main difference between the nontreatment and the treatment section
was that the latter included a special inquiry lesson using technology that allow students
to manipulate variables and to visualize concepts to build an understanding of the
concepts. My approach to explanation was the same, however, in the treatment unit
students could see what they were learning because of the simultaneous use of
technology. Students took a test after the unit.

The treatment unit 2 was on electrostatics. Students were given an inquiry sheet
with open-ended prelesson questions. They were then given the login information to the
virtual lab. The lesson began with simulations showing the charge, electric field and
electric force field. They were shown a YouTube video demonstrating coulomb’s force
between two point charges separated by a finite distance and how it is directly
proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them. The handout given was an inquiry-based worksheet with website address for a simulation. Students were expected to collect data and further analyze it. The next part was problem solving with the necessary equations for force, electric field, potential, and potential energy. Students were also shown a simulation on vector components for it is required in the problems involving forces and electric field since both are vectors. Students were permitted to revisit the simulation while solving problems. Students wrote reflections about the lessons daily and maintained a journal. They took a test after the unit.

Students are also expected to complete numerical problems based on the unit. A concept interview was conducted after the treatment. The lesson plan for the treatment unit 2 is given in Appendix G. Various data were collected through the project on student understanding of concepts, long-term memory, student interest and motivation and on my attitude to teaching physics concepts.

Data Collection Instruments

My school, the American International school-Chennai is located in Chennai, a city in the south of India rich in culture and tradition. The school is mainly for children of people on short-term job assignments in the multinational companies and industries. Chennai is a city with a rich culture that is developing into a commercial city in the state of Tamil Nadu in South India and is the capital of the state. The local population speaks a language called ‘Tamil’. There are many languages and dialects and every state in the country of India has a different spoken language. The economic boom has brought many industries from various countries to Chennai. Examples would be the car manufacturers
such as Hyundai from Korea, Renault from France, and General Motors from the USA.
The Information Technology industry is at the peak now. There are also many expatriate Indians settled in the USA and Europe, coming back to India with their families for a few years. Children of all these families study in the school.

The AP Physics class was a group of 13 students with four females and nine males who were my experimental group for the capstone project. They had studied a year of conceptual physics before they took this course. All of them had a good fluency in the English language. In the AP class, three females and seven males were of Indian origin but with American citizenship. They are in India at present since their parents have come to India on job assignments. There is one female student of Indian and Chinese mixed ethnicity and two male students who are natives of Korea. The data sources of this research were well suited to the level of mental maturity of my students. They were all ready to be challenged and were vocal in their expressions. They have taken the course out of their own volition and were eager to make the best of it. All students in this group were from grades 11 and 12 and were aware of the academic rigor in the AP program. They had good note-taking skills and were capable of answering questions both in informal and formal interviews. The data collected were from three different sources for each question that helped in the triangulation of data. The triangulation matrix of data is given in Table 1.
Table 1
*Triangulation Matrix*

<table>
<thead>
<tr>
<th>Focus Questions</th>
<th>Data Source 1</th>
<th>Data Source 2</th>
<th>Data Source 3</th>
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<tr>
<td>Primary Question: What are the effects of using guided technology, including simulations and virtual labs on student understanding of concepts in AP Physics classes?</td>
<td>Pre and postunit student assessments</td>
<td>Pre and postunit student concept interviews</td>
<td>Pre and posttreatment surveys</td>
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<tr>
<td>What are the effects of the use of guided inquiry with technology on students’ long-term memory of physics concepts?</td>
<td>Post and delayed treatment assessment</td>
<td>Post and delayed treatment concept interviews</td>
<td>Post and delayed treatment surveys</td>
</tr>
<tr>
<td>What are the effects of the use of guided inquiry with technology on students’ interest and motivation?</td>
<td>Instructor field observations with prompts</td>
<td>Pre and posttreatment student nonconcept interviews</td>
<td>Pre and posttreatment student surveys and journaling with prompts</td>
</tr>
<tr>
<td>What are the effects of the use of guided inquiry with technology on my teaching and attitudes towards teaching?</td>
<td>Nontreatment and treatment observations by colleagues with prompts</td>
<td>Instructor weekly reflection journaling with prompts</td>
<td>Pre and posttreatment teacher surveys</td>
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A reflective journal is a place to store information that comes from private, internal thoughts and from conversations with others (Hendricks, 2009). Journaling is the simplest method of documenting reflection. I chose these data collection instruments particularly for the students in my action research. An informal ethnographic interview
(Mills, 2011) was conducted at the beginning and at the end of each unit. All the 13 students were interviewed. I prefer this type of interview since it is neither too structured nor totally unstructured. As Agar (1980) states, it allows researchers to have a ready set of questions to ask participants in a study (Mills, 2011). These questions helped to open up a conversation since questions were open ended. The data collected appeared more realistic than answers to a structured set of questions.

The pre and postunit assessments, concept and nonconcept interviews, and evaluation surveys after the intervention assessed the understanding of the concepts. The pre and postunit tests for the three units are given in Appendices C, F and I. The nonconcept interviews were in the form of questions as given in Appendix J. The concept interviews involved making a concept map, guidelines of which are given in Appendices K and L. The delayed tests after the treatments assessed the long-term memory of concepts. It was given 14 days after the postassessment and the students were not supposed to study for it. The assessment details are provided in Appendices M, N, and O for the nontreatment and the treatment units respectively. The most important quantitative data collection documents were teacher-made tests for pre, postunit, and delayed assessment.

I gauged student interest and motivation with questionnaires, surveys, students’ reflection journal and my observation records before and after the intervention. I made an attempt to quantify and explain these data through simple questionnaires that helped me rate the data to scale the variables in my focus and subquestions.

The student evaluation questionnaire for the three units and prompts for students’ journal are in Appendices P, Q, R, and S. My field observation and the subsequent
reflection journaling with prompts was a tool for me to record events, thoughts, and the effect of treatment on students’ interest and motivation. I used the same qualitative data collection methods for my colleague’s observation and had meetings to exchange notes. The prompts for my field observations are listed in Appendix T. My reflective notes along with the feedback from the observations of my colleague and teacher survey helped me to analyze my attitude towards this approach to teaching physics concepts. The observations were a reflection on my teaching and my attitudes to teaching.

The achievement levels of the students were categorized as low achievers comprising of one male student and two female students, middle achievers with three male students and one female student, and five males and one female student forming the high achievers. These levels were determined solely on the basis of the student performance in the pre and posttests after treatments.

The data sources as indicated in the data triangulation matrix helped me study the effects of guided inquiry with technology on students’ understanding of advanced physics concepts, the long-term retention, student attitude, interest and motivation, and my attitude to teaching physics concepts.

DATA AND ANALYSIS

The data were comprised of both qualitative and quantitative data. Qualitative data were in the form of nonconcept interviews, students and teachers’ reflection journals and a colleague’s class observation reports. The quantitative data were collected from student evaluation surveys, pre and posttests, delayed assessments and, pre, post and delayed concept interviews. These sources allowed for a triangulation of data and the
results were analyzed in detail to address the focus questions and subquestions of the research.

The data for understanding concepts concerned pre and postunit student assessments, concept and nonconcept interviews, and surveys. Figure 1 shows the pretests and posttests scores after the nontreatment and treatment units. The slight change in pretest and posttest in treatment 2 and the high preunit assessment score could be attributed to the students’ prior knowledge of electric charges, which was the topic dealt in treatment unit 2.

![Figure 1](image)

*Figure 1. Average scores from the pretest and posttest for the nontreatment and treatment units, (N=13).*

Table 2 shows the normalized gain that measured the fraction of the improvement that was obtained after posttests for all students and for high, middle, and low achievers. There was an overall improvement in the scores of students in the treatment. Treatment unit 1 data show a slightly higher percent change than the nontreatment with students of all achievement levels and the normalized gains support this. The data did show slight improvement in the understanding of concepts but was not statistically significant.
Table 2
Average Scores of Unit Preunit assessments and Postunit assessments for High-Achieving (n=6), Middle-Achieving (n=4) and Low-Achieving (n=3). Students for the Nontreatment and Treatment units, (N=13)

<table>
<thead>
<tr>
<th></th>
<th>Pretest (average)</th>
<th>Posttest (average)</th>
<th>Percent change</th>
<th>Normalized gain score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td>18.7</td>
<td>20.0</td>
<td>7.0</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>22.3</td>
<td>23.6</td>
<td>5.8</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Middle</strong></td>
<td>19.0</td>
<td>21.5</td>
<td>13.2</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>14.7</td>
<td>17.7</td>
<td>20.4</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Non treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>18.7</td>
<td>22.2</td>
<td>18.7</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>22.5</td>
<td>24.8</td>
<td>10.2</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>Middle</strong></td>
<td>18.3</td>
<td>23.3</td>
<td>27.3</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>15.3</td>
<td>21.0</td>
<td>37.3</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>Treatment 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>19.7</td>
<td>22.1</td>
<td>12.2</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>23.7</td>
<td>24.8</td>
<td>4.6</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>Middle</strong></td>
<td>19.8</td>
<td>22.8</td>
<td>15.2</td>
<td>0.58</td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td>15.7</td>
<td>19.0</td>
<td>21.0</td>
<td>0.36</td>
</tr>
<tr>
<td><strong>Treatment 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* The assessment was out of 25 points.

As a part of the concept interviews, students were asked to draw schematic diagrams and make a concept map, compare the nontreatment unit on Ohm’s law with the first treatment unit on Kirchhoff’s law, and note the connections if any. They were asked to explain their observations. The average scores for the pre and postunit concept interviews for the three units are given in Table 3.

The percent change in the pre and posttreatment scores in Table 3 depict an increase in the understanding in the nontreatment and both treatment units. The highest percent change was in treatment Unit 1, followed by treatment 2, and the lowest percent change was in the nontreatment unit. The normalized gains verify the results of the percent change analysis. The lesson was a guided inquiry with a very interactive virtual lab on Kirchhoff’s labs. The interactive animation allowed students to choose various
components and their values. The visualization appeared to have a positive impact on understanding. The Ohm’s law lesson chosen for the nontreatment unit was a topic of which students’ had prior knowledge and so that explains the slightly lower percent change in the comparison of scores for pre and postunit for nontreatment.

Table 3
Average Scores of Preunit and Postunit with Concept Interviews for Nontreatment and Treatment Units, (N=13)

<table>
<thead>
<tr>
<th></th>
<th>Preunit</th>
<th>Postunit</th>
<th>Percent Change (%)</th>
<th>Normalized gain preunit to postunit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nontreatment</td>
<td>20.1</td>
<td>23.6</td>
<td>17.4</td>
<td>0.71</td>
</tr>
<tr>
<td>Treatment 1</td>
<td>19.5</td>
<td>24.5</td>
<td>25.6</td>
<td>0.91</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>17.6</td>
<td>21.1</td>
<td>19.9</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Note. The assessment was out of 25 points.

The preunit and postunit data for the interviews indicate that there was increase in scores for each unit. Treatment unit 1 had the greatest increase. These data suggest that the intervention helped students to understand concepts. Also, the higher scores after the first treatment also suggested that the choice of virtual labs and simulations were more appropriate to the intervention. The high scores after the nontreatment unit reinforced the fact that students had prior knowledge of the topic used for the unit and learned more after the treatments.

The average scores for the various subtopics in all the three units for post and delayed treatment assessments after concept interviews are given in Figure 2.
Figure 2. Average scores for concept understanding for post and delayed assessments with concept interviews, (N=13).

The nonconcept interviews were in the form of a set of questions to be answered pre and postunits. These are given in Appendix J. The nonconcept interviews suggested that nearly 38% students strongly felt that virtual labs did make them do hands on work and allowed them to explore but did not facilitate much in their understanding. A student said, “I like the traditional methods with the teacher drawing suitable diagrams and explaining sequentially.” Another student said, “It was good, like real labs and more accurate but I like the traditional method.” Nearly 46% of the students said that guided inquiry through virtual labs and simulations definitely helped them to understand concepts and said that the success of understanding depended on the topics as well. There are certain topics that are better understood by the traditional method and a few that help when visualized.

A student said, “The learning was different as I understand and visualized it better.” Another said, “It was easier to visualize and so I think I understand it better.”
One high achiever said, “I understood the electric flux better when I watched the animation.”

The data for students’ perception of understanding of advanced physics concepts were collected using survey questions. The survey had questions that not only helped investigate the effects of guided inquiry using technology on the concept understanding, but long-term retention, students’ attitude, and motivation as well. The results are shown in Figure 3. The student evaluation survey results did not show a prominent increase in understanding and this could be attributed to the students’ having prior knowledge of the lesson chosen for the nontreatment unit. The higher ratings did depict a good understanding of the concepts though not a noteworthy increase due to the intervention alone.

![Figure 3. Rating for understanding with survey questions for nontreatment and treatment units, (N=13). Note. 1-Strongly agree; 2-Agree; 3-Somewhat agree; 4-Disagree; 5-Strongly disagree](image)
The data for long-term memory of concepts concerned post and delayed unit treatment assessments, post and delayed treatment, and concept interviews and post and delayed treatment surveys. The results for assessments concerning long-term memory of concepts are found in Table 4.

### Table 4
*Average Post and Delayed Unit Assessment Scores, Percent Change and Normalized Gain*

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Delay</th>
<th>Percent Change Postunit to Delay Unit (%)</th>
<th>Normalized Gain Postunit to Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nontreatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All (N=13)</td>
<td>18.7</td>
<td>20.0</td>
<td>20.2</td>
<td>1.0</td>
<td>0.04</td>
</tr>
<tr>
<td>High (n=6)</td>
<td>22.3</td>
<td>20.8</td>
<td>23.2</td>
<td>11.5</td>
<td>0.57</td>
</tr>
<tr>
<td>Middle (n=4)</td>
<td>19.0</td>
<td>21.5</td>
<td>20.3</td>
<td>-6.0</td>
<td>-0.34</td>
</tr>
<tr>
<td>Low (n=3)</td>
<td>14.7</td>
<td>17.7</td>
<td>17.0</td>
<td>-4.0</td>
<td>-0.096</td>
</tr>
<tr>
<td><strong>Treatment 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All (N=13)</td>
<td>18.7</td>
<td>22.2</td>
<td>22.3</td>
<td>0.4</td>
<td>0.036</td>
</tr>
<tr>
<td>High (n=6)</td>
<td>22.5</td>
<td>24.8</td>
<td>24.2</td>
<td>-2.4</td>
<td>-0.75</td>
</tr>
<tr>
<td>Middle (n=4)</td>
<td>18.3</td>
<td>23.3</td>
<td>23.0</td>
<td>-1.3</td>
<td>-0.176</td>
</tr>
<tr>
<td>Low (n=3)</td>
<td>15.3</td>
<td>21.0</td>
<td>19.7</td>
<td>-6.2</td>
<td>-0.33</td>
</tr>
<tr>
<td><strong>Treatment 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All (N=13)</td>
<td>19.7</td>
<td>22.1</td>
<td>21.1</td>
<td>-0.2</td>
<td>-0.35</td>
</tr>
<tr>
<td>High (n=6)</td>
<td>23.7</td>
<td>24.8</td>
<td>24.2</td>
<td>-2.4</td>
<td>-0.30</td>
</tr>
<tr>
<td>Middle (n=4)</td>
<td>19.8</td>
<td>22.8</td>
<td>21.0</td>
<td>-7.9</td>
<td>-0.82</td>
</tr>
<tr>
<td>Low (n=3)</td>
<td>15.7</td>
<td>19.0</td>
<td>18.0</td>
<td>-5.3</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

*Note.* Maximum raw score is 25.

I have compared the results of the delayed assessments to postunit assessments to determine long-term memory of concepts. The trend in the data clearly shows less long-term memory of concepts for the high, middle, and low achievers in general, than the
nontreatment unit and the normalized gains support this analysis. These data suggest that the intervention strategies were not effective with helping students have greater long-term memory of concepts.

Since it was an AP Physics class and students had a prerequisite of good scores in the introductory physics classes in order to take the course, it was quite difficult for me to categorize students as Low, Middle, and High-achievers though the class did have three students who needed more time to understand concepts. It is interesting to note that there was increased memory of the concepts from the nontreatment section as well. The increase in knowledge usually indicates that the students continued to use those concepts after the unit was complete. Students were required to know Ohm’s law and its application which was the topic for the nontreatment unit in order to understand the concepts on Kirchhoff’s laws dealt in treatment 1. Therefore, it was difficult to conclude whether the long-term memory was the effect of guided inquiry using technology since the units were not independent of each other. In addition, one of the reasons, as mentioned earlier could be the choice of the topic Ohm’s law as the nontreatment unit of which nearly 100% of the class had background knowledge.

The nonconcept interviews and explanations suggested that nearly 69% of them felt confident enough to teach the topics of the treatment units. One student said, “I will use the same method as the teacher and then do practice problems.” Another student said, “I am able to remember what I learned but would like a small hint.”

The memory retention of concepts after treatment 1 was more evident compared to long-term memory of treatment unit 2 concepts. Students were unanimous in their opinion that the animations and the virtual labs used for inquiry of Kirchhoff’s laws in
treatment 1 were far more interactive, superior and had scope for ample exploration as compared to the animations used for inquiry in the unit on electrostatics in treatment 2. A student noted, “The Kirchhoff’s lab looked more realistic and we had the advantage of making as many circuits as we wanted in order to review the laws whereas in the electrostatics animation, the variables were limited.” There are certain virtual labs such as Kirchhoff’s laws that involve problems and calculations but also allow for a recording of voltage and current from the virtual labs. This could be then used to verify the problem at hand that has been solved previously using Kirchhoff’s laws. Students suggested that online virtual lab and inquiry are more effective if accompanied by a data collection and a means to verify that data. Figure 4 shows the average student response to select survey questions concerning their perception of long-term memory in relationship to skills of confidence. These data suggest that guided inquiry with the use of technology such as virtual labs had no effect or negatively affected student understanding and retention of advanced physics concepts.
The data for student motivation and attitude concerned instructor field observations, pre, and posttreatment nonconcept interviews and posttreatment student surveys and journal reflections. The responses of students to the nonconcept interviews were indicative of their motivation and interest in learning physics concepts. The answers varied from stating their ambition to become engineers to just interest and love for the subject. A low-achieving student answered after the first treatment unit on Kirchhoff’s laws, “It was interesting, unique and more realistic than just drawings and lecturing.” A high achiever said, “It was easy to understand the more abstract concepts such as electric flux when there was an animation.” A quantitative analysis of select responses from the nonconcept interviews helped to assess the motivation, attitude and interest for the low, middle and, high achievers.
The graph in Figure 5 shows the survey results for motivation and attitude in the low, middle and high achievers after the treatments. Middle and High-achieving students had very high enthusiasm and asked questions much in all units and there was no change. The low-achieving students had lower enthusiasm and asked fewer question in the nontreatment. In treatment 1 their enthusiasm decreased but increased higher than the nontreatment in treatment 2. The positive attitude showed a prominent increase in the high and middle achievers after both the treatments as compared to the nontreatment for all levels of achievers.

Figure 5. Average rating for students’ attitude and motivation for High-Achieving (n=6), Middle-Achieving (n=4) and Low-Achieving (n=3) with student nonconcept interviews for the nontreatment and treatment units, (N=13).

Note. 5-Strongly agree; 4-Agree; 3-Somewhat agree; 2-Disagree; 1-Strongly disagree

The study of the effects of guided inquiry using technology, such as virtual labs and animation on student attitude, interest, and motivation also included my observation that were recorded in my journal pre, postunit, and during nontreatment and treatment units. My qualitative observations were that students appeared to enjoy collaborative
work. They were seen discussing the methods and answering and arguing intermittently while solving the problems. They appeared to understand the sequence well and were quite eager to apply what they have learned. It was satisfying to note that students solved the questions given to them in the given time and looked motivated and confident. The interest was more evident after the second treatment. The nontreatment unit as mentioned earlier was on Ohm’s law of which students had a prior knowledge of so it was not surprising that they were interested. In general, I observed that students were very keen to learn the unit on electrostatics, which was my second treatment unit and this interest and motivation, and positive attitude is definitely caused by the intervention in the first treatment. Students enjoyed working on the virtual lab for making circuits during the unit on Kirchhoff’s laws. The classroom atmosphere was very positive. There was a mild decline in the enthusiasm during and after the second treatment, which I would now clearly attribute to my improper choice of animations for this second treatment unit.

Also, from my observations as recorded in my reflection journal, I have noted that pre and posttreatments show a prominent increase in the interest, motivation and confidence after the first treatment especially among middle and low achievers. The attitude, interest, and motivation was studied with the select variables. Figure 6 shows that there is interest and a positive attitude towards learning physics among the high achievers but it is not conclusive whether the high rating is due to the interventions. They appear to be motivated the same way irrespective of the type of treatment.

However the noticeable increase in motivation among the middle and low achievers who constitute 54% of the class indicated that guided inquiry using technology
does have a positive effect on students’ motivation, attitude, and interest in learning advanced physics concepts.

![Average rating for students' attitude and motivation for High-Achieving (n = 6), Middle-Achieving (n=4) and Low-Achieving (n=3) with teacher reflections for the nontreatment and treatment units, (N=13).](image)

**Figure 6.** Average rating for students’ attitude and motivation for High-Achieving (n = 6), Middle-Achieving (n=4) and Low-Achieving (n=3) with teacher reflections for the nontreatment and treatment units, (N=13).

**Note.** 5-Strongly agree; 4-Agree; 3-Somewhat agree; 2-Disagree; 1-Strongly disagree

I have selected responses to specific questions from the student survey responses to check for attitude, interest and motivation of students’ towards learning advanced physics concepts through guided inquiry using technology. Figure 7 depicts the rating of the survey responses taken postunit in the nontreatment, and the two treatment units. It could be noted that students enjoyed the Physics class irrespective of the type of treatments, however, the peak in the rating for interest and motivation in Figure 8 for the treatment units, suggest that guided inquiry with a good virtual lab and simulation does motivate students and make them interested in the learning of physics but had little change in their motivation according to the students’ perspective in the survey.
Figure 7. Average rating for select student response concerning enjoyment, engagement, and curiosity, \((N=13)\).

**Note.** 1-Strongly agree; 2-Agree; 3-Somewhat agree; 4-Disagree; 5-Strongly disagree

The data for investigating my attitude towards teaching using guided inquiry with technology concerned nontreatment and treatment unit observations by colleague, my weekly reflections and pre and posttreatment teacher surveys. My reflections on the daily lessons and class performance during and after nontreatment and treatment sessions focused on students’ understanding, retention, students’ attitudes, interest and my attitude towards teaching physics with guided inquiry using technology tools. The reflections were exhaustive spanning over nearly three weeks. I have studied my reflections and roughly rated select variables that will help me understand and study my attitude towards this method of teaching. The average rating using select variables to gauge my attitude and motivation is depicted in Figure 8. It appears that my attitude is very positive for both the nontreatment and treatments units and the satisfaction of having taught the advanced physics concepts advanced with the treatment units. Qualitatively, the nontreatment unit
was very satisfactory as well but this could well be attributed to the student’s prior knowledge of the topic that naturally encouraged a very positive, interactive classroom atmosphere. My attitude increased with the treatment and by the end of treatment 2 my level of satisfaction increased. By the end of the treatment units, my interest and satisfaction exceeded my already high-level motivation.

![Figure 8. Average teacher rating for teacher’s attitude and motivation.](image)

*Note.* 5-Strongly agree; 4-Agree; 3-Somewhat agree; 2-Disagree; 1-Strongly disagree

The colleague who observed my class during the nontreatment and treatment unit is also a postgraduate in physics and currently teaches mathematics in the school. I requested my colleague to fill a simple survey after each of the nontreatment and treatment sections. The prompts for colleague’s observation are provided in Appendix T.

In my informal conversation with the colleague after each observation, there was a mention about students’ focus on tasks since it depended on actual doing rather than just listening to the teacher. The colleague also observed that the questions asked by
students were of higher order and this encouraged me as a teacher to give answers and also lead to more inquiry with the virtual labs. I selected specific variables that could help me determine the change in students’ interest and attitude and requested my colleague to answer a short survey. This helped me to quantify the data. Figure 9 quantifies the observation. One thing that stands out from the figure is the positive impact that teaching physics by blending guided inquiry with online simulations and virtual labs is the increase it had on my interest and attitude.

![Figure 9](image.png)

*Figure 9. Colleagues’ rating for teachers’ motivation and attitude for nontreatment and treatment units.*

*Note.* 1-Poor; 2- Satisfactory; 3-Good; 4-Very Good; 5-Excellent

**INTERPRETATION AND CONCLUSION**

My main focus question was to determine whether guided inquiry using technology such a virtual labs and simulations affected the understanding of advanced physics concepts. The pre and the postunit assessments showed increase in the understanding especially after the first treatment for low and middle achievers. A
common factor that occurred in all the data collected was that the nontreatment unit chosen was a topic of which students had a prior knowledge. The post and the delayed assessments showed an increase in understanding but it was difficult to conclude whether it was due to the interventions alone.

My next aim was to study the effects of guided inquiry using technology, such as virtual labs and online simulations, on the long-term memory of concepts. A comparative study of the posttests with the delayed assessments for the nontreatment and the treatments showed similar results for the high, middle, and low achievers. The results show that although there was decay after the posttests, overall there was an increase in long-term memory.

The data collected were then analyzed to determine students’ interest, motivation, and attitude and it could be said that here the results were quite conclusive. The reflections in the student journal clearly showed increased motivation and interest after the treatments. Student responses to specific selected variables to check for interest, attitude, and motivation that were taken before and after treatments with nonconcept interviews and surveys also indicated increased motivation, positive attitude and interest. My reflections that were recorded in a journal during and after the interventions also support this conclusion. There was increased collaboration, focus, and interest to explore especially after that first treatment as compared to the second.

Finally, my goal was to see whether using inquiry with technology motivated me and changed my attitude towards teaching advanced physics. The rating of the select variables from my reflections show increased motivation and a positive impact on the
attitude to teaching physics. The ratings clearly show a peak for the treatment units. One of the data sources were a colleagues’ class observation.

My conversations with my colleague after observation and on analyzing the responses from a survey comprising of select questions rated by the colleague to check my attitude, suggested that blending guided inquiry with technology such as virtual labs and online simulations did have a positive effect on my teaching physics concepts in Advanced Placement physics classes.

VALUE

I believe my students have benefited by this research. My school is attempting to be one to one very soon with every single student getting access to a laptop or iPad. This study will encourage my school to explore online lessons, and search for interactive labs and resources not only for physics but other subjects as well. I have a positive approach towards learning and technology interests me. I am constantly in search of new applications that will help me improve the process of learning for students. This study has made me aware that inquiry using technology helps me first in visualizing concepts and, thus, enables me to help motivate students. The limitations for the study were the size of the student sample and the ethnicity. The students were mainly of Asian origins who are American citizens. It would have been good to have a mixed global population to be able to generalize.

The students in the study were from the AP Physics class who had their mock exams in April. It is quite possible that students reviewed the lessons at home and that could be reason there was not much of difference in their posttests and delayed assessment scores. I would like to conduct this study a little differently if I take up the
research again, by taking a regular introductory Physics class that has 40 students as my experimental group. The sample, therefore, would be larger and most importantly choose units of which students do not have a prior knowledge of. Guiding inquiry using technology has made it easier for me and fun for the students in the physics classroom. Also, these students would be less inclined to study between assessments.

This study has changed my professionalism. It has definitely encouraged me to be open minded and welcome change in education in this century and has encouraged me to collect data to help me make decisions about my teaching. I had used this method of teaching physics concepts earlier and had noted that students liked the approach and that was one of the reasons I chose this as my research topic. This is the first time I have collected such a large amount of data and used various data collection instruments and this has allowed me to advance in my professionalism. The most challenging part was to complete the data collection in the stipulated amount of time. The students were from the AP Physics class and they do not have classes after the spring break and are required to take their mock exams. Long-term memory of concepts has always been my primary focus as an educator. The results of this study did show long-term memory of concepts but highlighted the motivation, interest and attitude of the students and the teacher. In the future, for investigating the long-term memory, I would choose virtual labs that involved data collection, with interactive lessons that explain the answer to questions that are posed in them and make sure technology makes the abstract concepts as visual as possible. I should use the Internet effectively and identify very appropriate, interactive, and student friendly virtual labs, simulations and software and simultaneously use the constructivist approach.
I believe that Technology is here to stay and with the wealth of information from all over the world and Internet acting as a common platform for all educators to share their knowledge, using virtual labs, simulations and interactive lessons will help students to be motivated to learn physics.
REFERENCES CITED


APPENDIX A

PROJECT TIMELINE
January 14, 2013: Started nontreatment unit
Ohm’s law, concept of voltage current and resistance
Concept interview
Discussion with inquiry and open ended questions
Students submit the worksheet at the end of lesson.
Homework: Reflection Journal by students
Teacher’s observation journal

January 17, 2013: Modeling problems on Ohm’s law; First Observation by colleague
Solve numerical problems on Ohm’s law.
Concept interview, postunit assessment

January 21, 2013: Treatment unit 1
Kirchhoff’s laws – the Junction theorem and the loop theorem.
Preunit assessment, nonconcept and concept interviews and Survey
Handout with inquiry questions and link/login to a virtual laboratory
Discussion with inquiry and open ended questions
Homework: Reflection Journal by students
Teacher’s observation journal

January 23, 2013: Modeling problems on Kirchhoff’s law; Second observation by colleague.


January 29, 2013: Treatment Unit 2
Topic: Concept of charge, test charge, Coulomb force with numerical application
Concept of electric field, compare electric field and gravitational field. Comparison of inverse square laws, the law of gravitation and Coulomb’s law in electrostatics.
Preunit assessment, nonconcept and concept interview and survey.
Handout with inquiry questions and link/login to a virtual laboratory

February 1, 2013: Discuss and analyze data collected from the virtual lab.

February 6, 2013: Solve problems on electric field. Third observation by colleague

February 8, 2013: Concept of potential energy, potential and potential difference. Solve numerical problems.

February 12, 2013: Discussion and analysis of data collected.

February 14, 2013: Solve problems on potential energy and potential. Postunit assessment
February 18, 2013; Nonconcept Concept interview and survey, Delayed assessment for treatment unit 1

March 6, 2013: Delayed assessment for treatment unit 2.
APPENDIX B

NONTREATMENT LESSON PLAN
Nontreatment lesson plan

**Teacher:** Jayanthi R

**Course:** AP Physics

**Time duration:** 4 block periods of 90 minutes each.

<table>
<thead>
<tr>
<th>Class Announcements</th>
<th>'Reflections’ of today’s lesson is mandatory. Please follow the prompts provided.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials needed</strong></td>
<td>Physics Notebook</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Concept of voltage, current and resistance. Ohm’s law. Resistors connected in series and parallel. Apply Ohms law to resistor networks and solve problems involving voltage current and resistance.</td>
</tr>
<tr>
<td><strong>Background knowledge</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Vocabulary</strong></td>
<td>Potential difference, voltage, current, Ohm’s law, network, series and parallel resistor circuits.</td>
</tr>
<tr>
<td><strong>The teaching process</strong></td>
<td>Topic: Ohm’s law. Explanation and definition of the current, voltage (potential difference) and resistance is given. Ohm’s law is explained with schematic diagrams on the board with various values of Voltage, current and resistance. Schematic diagrams showing resistors in series are shown. Students are asked to take notes and copy the diagram. The equation for the effective resistance for a combination of resistors in series is shown. Ohm’s law is used and reiterated. Schematic diagrams showing resistors in parallel are shown. Students are asked to take notes and copy the diagram. The equation for the effective resistance for a combination of resistors in series is shown. A classwork sheet comprising of numerical problems is provided to the students. Students are required to solve the problems. They are allowed to refer to the notes taken earlier during the lesson. The lesson is delivered by a strict lecture method. All tasks are to be completed and submitted.</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td>State and explain Ohm’s law. Solve numerical problems involving resistor networks.</td>
</tr>
<tr>
<td><strong>Classwork Tasks</strong></td>
<td>Class work sheet. Solve numerical problems</td>
</tr>
<tr>
<td><strong>Homework tasks</strong></td>
<td>Daily reflection of the lesson in the journal</td>
</tr>
</tbody>
</table>
APPENDIX C

PRE AND POSTUNIT ASSESSMENT FOR NONTREATMENT LESSON
TEST
Ohm’s law and Series–Parallel networks
Show steps in calculations

1) A light bulb operating at 110 V draws 1.40 A of current. What is its resistance?
   A) 109 Ω B) 78.6 Ω C) 154 Ω D) 12.7 Ω

2) What is the total resistance of the circuit in Figure 19-3 above? 
   A) 950 Ω B) 257 Ω C) 392 Ω D) 450 Ω

3) What is the potential of point A relative to point C in Figure 19-3 above? 
   A) +4.0 V B) +6.0 V C) +3.0 V D) +2.0 V
4) If $E = 4.0 \, \text{V}$, what is the current through the 20 ohm resistor in Figure above?

A) 4.0 A  B) 0.017 A  C) 0.0077 A  D) 0.040 A

5) Two resistors of 5.0 and 9.0 $\Omega$ are connected in parallel. A 4.0-$\Omega$ resistor is then connected in series with the parallel combination. A 6.0-V battery is then connected to the series-parallel combination. What is the current through the 9.0-$\Omega$ resistor?  ______

A) Zero  B) 0.53 A  C) 0.30 A  D) 0.83 A

6) For the circuit in Figure above, determine the current in the 1-$\Omega$ resistor.  ______

A) 3.2 A  B) 0.90 A  C) 2.8 A  D) 1.2 A

References

APPENDIX D

TREATMENT UNIT 1 LESSON PLAN
Treatment unit 1 lesson plan

**Teacher:** Jayanthi R

**Course:** AP Physics

**Time duration:** 4 block periods of 90 minutes each.

<table>
<thead>
<tr>
<th>Class Announcements</th>
<th>‘Reflections’ of today’s lesson is mandatory. Please follow the prompts provided.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials needed</strong></td>
<td>Physics Notebook, Calculator, Laptop with internet facility</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Kirchhoff’s laws for simple and complex networks.</td>
</tr>
<tr>
<td></td>
<td>Single loop and multi loop circuits.</td>
</tr>
<tr>
<td></td>
<td>Kirchhoff’s laws for circuits with two or more emfs.</td>
</tr>
<tr>
<td><strong>Background knowledge</strong></td>
<td>Definition Electric Current, Ohm’s Law: Resistance and Resistors, Resistors in Series and in Parallel. Solve problems for current and voltage for series and parallel networks of resistors using Ohm’s law.</td>
</tr>
<tr>
<td><strong>Vocabulary</strong></td>
<td>Potential difference, voltage, current, Ohm’s law, network, series and parallel resistor circuits, Kirchhoff’s Voltage law (loop theorem), Kirchhoff’s current law (Junction theorem)</td>
</tr>
<tr>
<td><strong>Learning goals</strong></td>
<td>Recognize the similarities and differences between Kirchhoff’s current and voltage laws. Apply Kirchhoff’s laws to single loop and multi loop circuits. Solve for current and potential difference in circuits involving two or more sources of emf.</td>
</tr>
<tr>
<td><strong>The teaching process</strong></td>
<td>Teacher guided lesson using simulations and a virtual lab: Topic: Kirchhoff’s laws for electric networks. Watch the following animations: Kirchhoff’s current law. (Junction theorem) <a href="http://www.regentsprep.org/Regents/physics/phys03/bkirchof1/default.htm">http://www.regentsprep.org/Regents/physics/phys03/bkirchof1/default.htm</a> Kirchhoff’s voltage law, (Loop theorem) <a href="http://www.regentsprep.org/Regents/physics/phys03/bkirchof2/default.htm">http://www.regentsprep.org/Regents/physics/phys03/bkirchof2/default.htm</a>. Take notes. Handout for inquiry and virtual lab website login details are given. Students to follow instructions in the inquiry sheet and work accordingly. Apply Kirchhoff’s laws to single loop and multi loop circuits. Solve for current and potential difference in circuits involving two or more sources of emf. (Students may refer to the simulations while solving the problems in the given worksheet).</td>
</tr>
</tbody>
</table>
All tasks are to be completed and submitted.

<table>
<thead>
<tr>
<th>Skills</th>
<th>Apply Kirchhoff’s current and voltage laws and simplify networks and to determine and current and potential difference in circuits.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classwork Tasks</td>
<td>Class work - Data collection using the virtual lab simulation. Process the data and draw conclusions. Solve numerical problems</td>
</tr>
<tr>
<td>Homework tasks</td>
<td>Daily reflection of the lesson in the journal</td>
</tr>
</tbody>
</table>

References


APPENDIX E

HANDOUT FOR VIRTUAL LAB INQUIRY FOR TREATMENT UNIT 1
HANDOUT FOR VIRTUAL LAB INQUIRY FOR TREATMENT UNIT 1

Virtual Circuit Lab Kirchhoff’s Laws

Purpose:
Part 1. Verify Kirchhoff’s laws when applied to circuits with single emf.
Part 2. Verify Kirchhoff’s laws when applied to circuits with multiple emfs.

Go to http://phet.colorado.edu/en/search?q=circuits

The website is user friendly and allows you to choose resistors, their values, the emfs their values and enables you to try out multiple networks.
Part 1: Connect a single loop comprising of four resistors and a single emf. You may choose the values. Calculate the potential difference across each of the resistors and the currents through them using Kirchhoff’s laws. Verify by actually making the measurements for the voltage and current using the virtual voltmeter and ammeter.

Part 2: Connect multiple loops comprising of four resistors and two emfs. You may choose the values. Calculate the potential difference across each of the resistors and the currents through them using Kirchhoff’s laws. Verify by actually making the measurements for the voltage and current using the virtual voltmeter and ammeter.

References

http://phet.colorado.edu/en/search?q=circuitsReferences:

APPENDIX F

PRE AND POSTUNIT ASSESSMENT FOR TREATMENT UNIT 1
Test: Kirchhoff’s laws
Solve the following problems using Kirchhoff’s laws. Show the steps in calculations where necessary.

1) State Kirchhoff’s junction rule.
2) A 22-A current flows into a parallel combination of 4.0 Ω, 6.0 Ω and 12 Ω resistors. What current flows through the 12-Ω resistor? ______
   A) 18 A B) 7.3 A C) 3.7 A D) 11 A

3) What current flows in the 12-Ω resistor in Figure above? ______
   A) 1.0 A B) 0.75 A C) 0.25 A D) 0.50 A

4) Three resistors of 12, 12, and 6.0 Ω are connected in series. A 12-V battery is connected to the combination. What is the current through the battery? ______
   A) 0.10 A B) 0.30 A C) 0.20 A D) 0.40 A

5) What current flows in the solid wire connecting the upper left and lower left corners of the circuit below? ______
   A) 0.25 A B) 1.0 A C) 0.50 A D) 0.75 A
6) Determine the current in the 7-Ω resistor in Figure below
A) 0.28 A B) 1.6 A C) 2.1 A D) 1.3 A

References

APPENDIX G

TREATMENT UNIT 2 LESSON PLAN
Treatment unit 2 lesson plan

**Teacher**: Jayanthi R

**Course**: AP Physics

**Time duration**: 4 block periods of 90 minutes each.

<table>
<thead>
<tr>
<th>Class Announcements</th>
<th>‘Reflections’ of today’s lesson is mandatory. Please follow the prompts provided</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials needed</strong></td>
<td>Physics Notebook, Calculator, Laptop with internet facility</td>
</tr>
</tbody>
</table>
| **Objectives**       | Concept of static charges  
Types of electric charges and their properties  
Concept of test charge  
Coulomb’s law in electrostatics, electric field and potential, solve problems involving electric force and field vectors and electric potential. |
| **Background knowledge** | Potential difference and current applied to electric circuits |
| **Vocabulary**       | Positive charge, negative charge, test charge, line of electric force, point charges, coulomb force, electric field, electric potential energy, electric potential, vector resolution |
| **Learning goals**   | Recognize types of charges and their properties.  
Define a test charge and explain its properties.  
State Coulomb’s law in electrostatics and write the equation for force.  
Define and derive equations for the electric field.  
Define work done in moving a charge in an electric field and hence define electric potential.  
Derive equations for Electric potential energy and electric potential.  
Recognize that force and electric field intensity are vectors and electric potential energy and potential are scalars  
Solve problems involving electric field and force using laws and properties of vectors. Solve problems involving electric potential energy and electric potential. |
| **The teaching process** | Teacher guided lesson using simulations and a virtual lab.  
Concept of charge and electric field.  
Students are given a handout with inquiry questions and the website url.  
http://phet.colorado.edu/en/simulation/electric-hockey  
Students take notes on their observations and collect data as per |
Students are given a handout with inquiry questions and the website url. http://phet.colorado.edu/en/contributions/view/3464

Students take notes on their observations and collect data as per the instruction in the handout.

Apply the concepts to the numerical problems in the classwork sheet. (Students are allowed to refer to the simulations while solving the problems)

All tasks are to be completed and submitted to the teacher.

<table>
<thead>
<tr>
<th>Skills</th>
<th>Apply concepts of electric force, field, potential energy and potential to solve numerical problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classwork Tasks</td>
<td>Class work - Data collection using the virtual lab simulation. Process the data and draw conclusions. Solve numerical problems</td>
</tr>
<tr>
<td>Homework tasks</td>
<td>Daily reflection of the lesson in the journal</td>
</tr>
</tbody>
</table>

References


APPENDIX H

HANDOUTS FOR INQUIRY TREATMENT UNIT 2
Handout for inquiry-

1. Static charges and Electric field

**Purpose:** to investigate the properties of electric charges and electric field.

**Procedure:**

Design a simple virtual experiment to investigate the properties of electric charge and electric field. Qualitatively and with suitable diagrams explain your observations.

Handout for inquiry -2. Electric Field

**Purpose:** To investigate the direction and magnitude of electric field lines that is created around positive and negative charges.

**Procedure:**

Design an experiment to explain the dependence of electric field on
   a) the magnitude of the electric charges
   b) the distance from the electric charges
   c) the nature of the point charge.

Qualitatively and with suitable diagrams explain your observations.

**References**


APPENDIX I

PRE AND POSTUNIT ASSESSMENT FOR TREATMENT UNIT 2
TEST
Electric field and Electric potential
Show the steps in calculations where necessary.

1) A point charge of +Q is placed at the centroid of an equilateral triangle. When a second charge of +Q is placed at one of the triangle's vertices, an electrostatic force of 4.0 N acts on it. What is the magnitude of the force that acts on the center charge due to a third charge of +Q placed at one of the other vertices?

2) _______
A) 8.0 N B) zero C) 16 N D) 4.0 N

3) A 5.0-C charge is 10 m from a small test charge. What is the magnitude of the force experienced by a 1.0 nC charge placed at the location of the test charge? _______
A) 0.45 N B) 45 N C) 4.5 N D) 0.045 N

4) Consider a square which is 1.0 m on a side. Charges are placed at the corners of the square as follows: +4.0 μC at (0, 0); +4.0 μC at (1, 1); +3.0 μC at (1, 0); -3.0 μC at (0, 1). What is the magnitude of the electric field at the square's center? _______
A) $1.7 \times 10^5$ N/C B) $1.1 \times 10^5$ N/C
C) $1.3 \times 10^5$ N/C D) $1.5 \times 10^5$ N/C

5) The force between a 30-μC charge and a -90-μC charge is 1.8 N. How far apart are they? 36) _______
A) 1.9 m B) 4.2 m C) 3.7 m D) 2.3 m

44) The absolute potential at a distance of 2.0 m from a positive point charge is 100 V. What is the absolute potential 4.0 m away from the same point charge? _______
A) 25 V B) 400 V C) 200 V D) 50 V

6) An equipotential surface must be _______
A) parallel to the electric field at any point.
B) perpendicular to the electric field at any point.

7) Two parallel plates, separated by 0.20 m, are connected to a 12-V battery. An electron released from rest at a location 0.10 m from the negative plate. When the electron arrives at a distance 0.050 m from the positive plate, how much kinetic energy
does the electron gain?  
A) 9.6 × 10⁻¹⁹ J  B) 2.4 × 10⁻¹⁹ J  
C) 7.2 × 10⁻¹⁹ J  D) 4.8 × 10⁻¹⁹ J  

8) A 5.0-nC charge is at (0, 0) and a -2.0-nC charge is at (3.0 m, 0). If the potential is 
taken to be zero at infinity, what is the electric potential energy of a 1.0-nC charge at 
point (0, 4.0 m)?  
A) 1.5 × 10⁻⁸ J  B) 3.6 × 10⁻⁹ J  C) 7.7 × 10⁻⁹ J  D) 1.1 × 10⁻⁸ J  

References  
APPENDIX J

STUDENT NONCONCEPT INTERVIEWS
Student interview (Nonconcept) (Both pretreatment and posttreatment)

1. What are/were your expectations from this lesson? Explain.

2. Where in the lesson do you think you have the most difficulty in understanding? Explain.

3. What section of the lesson is the least difficult/easy for you? Explain.

4. What do you think are your shortcomings (if any) while you were doing the problems in the lesson? Explain.

5. When during the lesson did you realize this problem? Explain.

6) What teaching strategies help you learn best? Explain

7) How motivated are you to learn physics? Explain.

8) What motivate you to learn physics? Explain.

9) Do you feel confident enough to explain the concepts you have learned to another individual? Explain the methods you will use.

(Post treatment)

1) How different was the learning when the inquiry was guided with animations and simulations? Explain.

2) How was your experience collecting data in a virtual lab? Explain

3) What were the limitations and difficulties you had while collecting data from a virtual lab?

4) Do you feel confident enough to explain the concepts you have learned to another individual? Explain the methods you will use.
APPENDIX K

STUDENT CONCEPT INTERVIEWS FOR TREATMENT UNIT 1
[PRE, POST, AND DELAYED]
Student concept interview

Draw a schematic network consisting of a single loop using resistors and voltage sources. Create a concept map to show the steps in solving a numerical problem using Kirchhoff’s laws.

1. Show steps in solving the networks for relevant current and voltage drops.

2. Draw a schematic network consisting of multiple loops using resistors and voltage sources. Create a concept map to show the steps in solving a numerical problem using Kirchhoff’s laws.

3. Show steps in solving the networks for relevant current and voltage drops.

4. From your understanding of Ohm’s law and Kirchhoff’s laws do you notice a connection between them? If so, explain with suitable circuit diagrams and examples.
APPENDIX L

STUDENT CONCEPT INTERVIEWS FOR TREATMENT UNIT 2
[PRE, POST, AND DELAYED]
Student concept interview

Student Interview (Concept)

1. Create a detailed concept map to show the concepts in electrostatics. Your map should be methodical and sequence should be correct. It should include, charges and their properties, Coulomb’s law, electric field intensity, electric potential energy and electric potential. The map should also include simple problems showing the application of the concepts.

2. Create a PowerPoint of 10 slides to include the main concepts in the unit and their explanation. Include numerical examples in the PowerPoint.

3. How would you explain the difference between electric field and electric potential and the relation between the two quantities?
APPENDIX M

DELAYED ASSESSMENTS NONTREATMENT UNIT
1. Find the equivalent resistance of these series circuits (in Ω) (2 points)

   a) \( R_1 = 100 \, \Omega \)
   \( R_2 = 20 \, \Omega \)
   \( R_3 = 55 \, \Omega \)

2. Find the equivalent resistance of these parallel circuits (in Ω) (2 points each)

   a) \( R_1 = 100 \, \Omega \)
   \( R_2 = 20 \, \Omega \)
   \( R_3 = 55 \, \Omega \)

3. Calculate the equivalent resistance of the following circuits (2 points each)

   a) \( R_1 = 5 \, \Omega \) \( R_2 = 10 \, \Omega \)

   ![Diagram](image1)

   b) \( R_1 = R_2 = R_3 = 1.5 \, \Omega \)

   ![Diagram](image2)

   c) \( R_1 = 12 \, \Omega \) \( R_2 = 5 \, \Omega \) \( R_3 = 8 \, \Omega \)

   ![Diagram](image3)
4. Three light bulbs of 4 Ω resistance each are in a parallel with a 9V power supply. Draw the circuit, and find the current. (3 points)

5. Three identical buzzers are in parallel with a 110 V power supply. The circuit has a current of 1.5 A. Draw the circuit. Find the resistance of one buzzer. (3 points)

References

APPENDIX N

DELAYED ASSESSMENTS TREATMENT UNIT 1
Test

Analyze the following circuit to assist your understanding of setting up equations using Kirchhoff’s Laws.

1. Which letters represent junctions?
2. Are these junctions equivalent?
3. Write this junction equation.
4. Why are A and B not considered junctions?

For the remainder of the worksheet, \( R = 5 \) ohms and the emf of the battery equals \( 20 \) V.

1. Write the equation of the loop EDCAE.
2. Write the equation of the loop EFBCAE.
3. Write the equation of the loop EDCFE.
4. Write the equation of the loop ACBA.

5. What is the magnitude of each current?

6. What does a negative current mean?

7. What is the voltage across AB?

8. How important are the loop directions in solving the problem for currents? Why?

References

APPENDIX O

DELAYED ASSESSMENT ASSESSMENTS TREATMENT UNIT 2
Show neat diagrams and steps in your calculation. (Given: Coulomb’s constant \( k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2 \)).

Note that points will be given to the steps in calculations.

1. Two charges 2C and -5C are kept 2m apart. Calculate the net force acting on a 1C charge placed exactly midway in the line joining the two charges. (4 Points)

2. Four charges of equal magnitude +Q are placed one each on the four corners of a square of side 1m. Calculate
   a) the net electric field at the center of the square.
   b) the net electric potential at the center of the square.
   (6 points)

3. What is the electric potential energy of a 2C charge at a distance 3m from -10C charge? (4 points)

4. Why is it important to use the word ‘point’ charges while stating Coulomb’s law in electrostatics? Write two sentences. (4 points)

5. Two charges -10C and 5C are placed 2m apart. Determine a point on the line joining the two where the electric field intensity is zero. (6 points)
Student Evaluation Survey-
1-Strongly agree; 2-Agree; 3-Somewhat agree; 4- Disagree; 5-Strongly disagree

I was able to understand the difference between current and voltage.
1 2 3 4 5

I am confident about using the Ohm’s law.
1 2 3 4 5

I have previous knowledge about Ohm’s law and single loop circuits
1 2 3 4 5

I will be able to use calculate the variables V, I and R using Ohm’s law..
1 2 3 4 5

I understand the directions in which the conventional current flows and its significance.
1 2 3 4 5

I will be able to solve problems involving two or more resistors.
1 2 3 4 5

I will be able to apply Ohm’s law to simple resistor circuits and complex multiloop circuits.
1 2 3 4 5

I am able to visualize how resistors could be connected to give a desired value by suitably connecting them in series and parallel.
1 2 3 4 5

I understand that in resistors in series the current is a constant.
1 2 3 4 5

I understand that in a parallel connection of resistors, the potential difference or voltage is a constant.
1 2 3 4 5

I enjoy going to Physics class.
1 2 3 4 5

Explain

This class keeps me engaged and interested.
1 2 3 4 5

Explain

I am curious about the concepts we are studying.
1 2 3 4 5

Explain
I am confident in my understanding of the material we studied in this unit.

1 2 3 4 5
Explain

If I were given a quiz on the previous unit today, I would be able to earn a good grade.

1 2 3 4 5
Explain

What class activities help you learn the most?
Explain.

What class activities keep your interest the most?
Explain

8) What did you enjoy most about this unit? Explain.

9) What did you find most frustrating about this unit? Explain.

10) Is there anything else you would like to tell me about the work you did in class during this unit?
APPENDIX Q

STUDENT EVALUATION SURVEY FOR TREATMENT UNIT 1
Student Evaluation Survey-
1-Strongly agree; 2-Agree; 3-Somewhat agree; 4- Disagree; 5-Strongly disagree

I was able to understand the direction of current flow in multiloop circuits.
1 2 3 4 5

I am confident about using the Kirchhoff’s current law
1 2 3 4 5

I have previous knowledge about Ohm’s law and single loop circuits
1 2 3 4 5

I will be able to use Kirchhoff’s voltage law correctly.
1 2 3 4 5

I understand the directions in which the loops in circuits have to be chosen and their significance.
1 2 3 4 5

I will be able to solve problems involving multiple voltage sources.
1 2 3 4 5

I will be able to apply Kirchhoff’s laws to simple resistor circuits and complex multiloop circuits.
1 2 3 4 5

I am able to identify and relate the laws with conservation of charge and energy.
1 2 3 4 5

I understand that the direction of the loop is important while solving for currents in circuits.
1 2 3 4 5

I understand how currents could have different directions.
1 2 3 4 5

I enjoy going to Physics class.
1 2 3 4 5

Explain

This class keeps me engaged and interested.
1 2 3 4 5

Explain

I am curious about the concepts we are studying.
1 2 3 4 5

Explain
I am confident in my understanding of the material we studied in this unit.

1 2 3 4 5

Explain

If I were given a quiz on the previous unit today, I would be able to earn a good grade.

1 2 3 4 5

Explain

What class activities help you learn the most?
Explain.

What class activities keep your interest the most?
Explain

The teaching style (technology for treatment units) keeps me interested in physics.

1 2 3 4 5

Explain

The teaching style (technology method for treatment units) is effective in helping me learn.

1 2 3 4 5

Explain

What did you enjoy most about this unit? Explain.

What did you find most frustrating about this unit? Explain.

Is there anything else you would like to tell me about the work you did in class during this unit?
APPENDIX R

STUDENT EVALUATION SURVEY FOR TREATMENT UNIT 2
Student Evaluation Survey

1-Strongly agree; 2-Agree; 3-Somewhat agree; 4- Disagree; 5-Strongly disagree

I was able to recognize the properties of positive and negative charges.
   1 2 3 4 5
I am aware that electric force and field are vectors.
   1 2 3 4 5
I have previous knowledge about Ohm’s law and single loop circuits
   1 2 3 4 5
I will be able to solve problems involving two or more charges.
   1 2 3 4 5
I understand that vector resolution principles are essential to solve problems
   1 2 3 4 5
I understand the concept of potential energy.
   1 2 3 4 5
I will be able to recognize equipotential points near a static charge.
   1 2 3 4 5
I am able to differentiate the terms electric field and electric potential.
   1 2 3 4 5
I understand that Coulomb’s force in electrostatics could attractive as well as repulsive.
   1 2 3 4 5
I understand the behavior of a test charge when placed near other point charges.
   1 2 3 4 5
I enjoy going to Physics class.
   1 2 3 4 5
Explain

This class keeps me engaged and interested.
   1 2 3 4 5
Explain
I am curious about the concepts we are studying.

1 2 3 4 5

Explain

I am confident in my understanding of the material we studied in this unit.

1 2 3 4 5

Explain

If I were given a quiz on the previous unit today, I would be able to earn a good grade.

1 2 3 4 5

Explain

What class activities help you learn the most?

Explain.

What class activities keep your interest the most?

Explain

The teaching style (technology for treatment units) keeps me interested in physics.

1 2 3 4 5

Explain

The teaching style (technology method for treatment units) is effective in helping me learn.

1 2 3 4 5

Explain

What did you enjoy most about this unit? Explain.

What did you find most frustrating about this unit? Explain.

Is there anything else you would like to tell me about the work you did in class during this unit?
APPENDIX S

TEACHER REFLECTION PROMPTS FOR STUDENT JOURNAL
Teacher reflection prompts for students’ journal

1. What are/were your expectations from this lesson? Explain your expectations from this lesson.

2. Where in the lesson do you think you have the most difficulty in understanding? What section was the most easy to understand? Explain.

3. What section of the lesson is the least difficult/easy for you? Explain.

4. What do you think are your shortcomings (if any) while you were doing the problems in the lesson? Explain.

5. When during the lesson did you realize this problem? Explain.

6. How do you think we can solve this problem? Explain.

7. How different was the learning when the inquiry was guided with animations and simulations? Explain.

8. How was your experience collecting data in a virtual lab? Explain

9. What were the limitations and difficulties you had while collecting data from a virtual lab?

10. Do you feel confident enough to explain the concepts you have learned to another individual? Explain the methods you will use.
APPENDIX T

TEACHER FIELD OBSERVATION AND JOURNAL PROMPTS
Teacher field observation and journal

How was the sequence flow of the lesson?

How did the students respond to the instructions? Explain

Did the students have any preconceptions? If so, how were they addressed?

Did the students complete the given task? Explain

Did the teamwork produce collaborative results? Explain

Were students enthusiastic participants in class this week? Explain.

What did students complain about this week? Explain

What positive comments did students make this week? Explain

What was the most satisfying aspect of class this week? Explain

What was the most frustrating aspect of class this week? Explain

How did students react to the teaching style (traditional or 5E method) this week? Explain

For each of the following give your rating
1-Strongly agree; 2-Agree; 3-Somewhat agree; 4- Disagree; 5-Strongly disagree

1) Students were attentive and on task for the majority of the class.
   1 2 3 4 5

2) Students had a positive attitude in class.
   1 2 3 4 5

3) Students were curious about the class topic.
   1 2 3 4 5

4) The teacher seemed enthusiastic and interested about the class.
   1 2 3 4 5