PROBLEM SOLVING IN PHYSICS: THE IMPACT OF GROUP STUDY IN DEVELOPING PROBLEM SOLVING SKILLS

by

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ABSTRACT

First-year, high school physics students struggle with problem solving in physics. They tend to show characteristics of novice problem solvers, such as fixating on finding an answer or neglecting to understand the principles behind the problem. Most of the in-class problem solving exercises are traditionally teacher-led. Students are expected to pay attention in class and work on developing their own skills as they work on homework. To address these difficulties, the treatment section engaged in group problem solving sessions in lieu of the teacher-led sessions. They were given a protocol to follow to work together at developing skills of expert problem solvers. During the treatment period, students in the treatment section showed small improvements on problem solving assessments when compared to their comparison counterparts. While there were small gains made, it might be best to employ multiple in-class problem solving methods throughout the year to foster the greatest development in problem solving skills for first-year physics students.

INTRODUCTION AND BACKGROUND

Augusta Preparatory Day School, a non-sectarian independent school in Martinez, Georgia, is located within the Central Savannah River Area (CSRA). It draws mainly from three counties within the CSRA, Aiken (SC), Columbia (GA) and Richmond (GA). The approximate combined population of these counties is 500,000. The total student population across the Lower, Middle and Upper Schools is around 550, with approximately 200 of those students enrolled in the Upper School. Tuition ranges from around $12,000 in the Lower School to around $15,000 in the Upper School. The school claims 24% ethnic diversity for the 2014-2015 school year. The representative counties have ethnic diversities of 29% (Aiken), 17% (Columbia) and 54% (Richmond). Median household incomes average $38,000 in both Aiken County and Richmond County and $65,500 in Columbia County.

In the Upper School, students are required to take four laboratory sciences to graduate and satisfy the requirements for admission into the University System of Georgia. Of the four courses required, one course must be in the physical sciences. Most students take a first-year physics course, choosing between College Preparatory Physics, a conceptual physics course, and Honors Physics, an algebra- and trigonometry-based course. I am currently in my fourth year of teaching the two sections of the Honors Physics course as part of my teaching load. The course has a small laboratory component, as the Upper School science facilities currently do not allow for an in-depth physics laboratory experience. The course therefore focuses on physics problem solving.

The problem solving component of the course has its difficulties. Students can show significant conceptual understanding and demonstrate a working knowledge of physical relationships but struggle to apply that conceptual understanding and knowledge in the problem solving process. When presented with a problem requiring one step to complete, students are generally able to identify the necessary relationship and solve the problem. However, when multiple steps are required in a problem, students do not exhibit the same level of success. They struggle to interpret the more challenging problem and identify intermediate steps required to solve the problem. It often appears as though students are attempting to find a shortcut through the more complex problems. They attempt to force a relationship on the given information instead of interpreting any implications the given information might have. One example was a student, since graduated, who repeatedly insisted on using a derived equation for the range of a projectile

$$R = \frac{{v_o}^2}{g}\sin(2\theta) \tag{1}$$

as opposed to the parametric motion equations

$$y = y_o + v_{o,y}t + \frac{1}{2}a_y t^2 \tag{2}$$

$$v_y = v_{o,y} + a_y t \tag{3}$$

$$x = x_o + v_{o,x}t \tag{4}$$

to solve problems concerning projectile motion. He forgot, ignored, or omitted the conditions required for the range expression (Equation 1), limiting its usefulness. He would have been much better served using the parametric equations (Equations 2-4) that can be employed for any projectile motion problem.

Some of the end results of these difficulties include generalizations and calculator reliance. Students will try to summarize multiple concepts into one overarching idea. When asking questions, they begin their query with the phrase "so what you are saying is", indicative of their desire to combine the ideas with which they are struggling with concepts they are already confident using. Oftentimes this forced combination of ideas is not a valid relationship. Calculator reliance comes about through a desire for any numerical solution, regardless of its basis in physical relationships. Students will attempt to combine any numbers given in a problem in a manner they feel might be correct because it gives an answer, ignoring whether that answer is plausible. This is often a source of stress for students as they are uncertain of the validity of their answers.

The problem solving component in Honors Physics primarily has included teacher-led practice. Following discussion of the concepts and presentation of new material with the class, I present and work towards solving various problems on the board appropriate to the new concepts. Students are expected to both ask, and answer questions during this process as part of their general engagement in the class. However, a student can, in the current arrangement, avoid gaining a strong understanding in the problem solving processes demonstrated or manage to get lost in the variety of steps taken. As a result, when problem solving assessments are presented at the conclusion of each chapter, some students are unable to demonstrate their understanding.

Purpose and Focus Question

The purpose of this action research project was to see how the problem solving skillset of first-year physics students could be improved by conducting problem solving practice sessions in groups with minimal instructor input. The research question for this project was: "What is the impact of peer grouping during problem solving sessions on the problem solving skills of high school physics students?" Additionally, the project endeavored to answer the following sub-questions:

1. "What problem solving skills and conceptual understanding do students gain from their peers through group study that they do not gain through a traditional classroom setting?"

2. "Will the dynamic of collaborative problem solving sessions influence students' classroom engagement?"

3. "Will the group problem solving exercises affect students' views concerning the study of physics?"

CONCEPTUAL FRAMEWORK

In the Next Generation Science Standards (NGSS) for high school physical science, there is a mathematical and computational thinking component to the science and engineering practices requirements (NGSS Lead States, 2013). Within these standards, students are expected to begin using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. (NGSS Lead States, HS-PS4-1, 2013)

These are the skills that students struggle with most in my classes. They have taken more than the requisite math, as concurrent enrollment in Precalculus is a requirement for Honors Physics. According to the National Center for Education Statistics, this is not a localized issue. In the Program for International Student Assessment (PISA) from 2012, students from the United States averaged a score of 497, roughly placing them at Level 3 in the PISA proficiency levels (Kelly, et.al., 2013). One of the main distinctions between Level 3 and Level 4 is that Level 4 proficiency measures the ability of students to interpret scenarios and make inferences, a hallmark of problem solving.

Problem solving in physics differs from problem solving in other fields. The problem solving process generally involves conceptually linking mathematical relationships to reveal the solution. The math may be perceived as an impediment to the problem solving process by students because of the diversity of methods that could potentially be utilized to solve a problem (Fredish, 2005). Even the process of evaluating and assessing problem solving in physics is cause for division, as at times a consensus cannot be reached on how to award credit for work done on a problem (Henderson et.al., 2001). Because of the divisions between experts about how to develop novice problem solvers, there exists a stark difference between experts and novices when it comes to problem solving in physics (Chi, Glaser, and Rees, 1981). Students just beginning their physics study struggle with problem solving for a variety of reasons. A major contributing reason is because of conceptual problems in determining what is being asked in the problem (Chi, Glaser and Rees, 1981). This is only one of many steps in the problem solving process, but because it occurs early in the process, it is crucial to students' development as physics problem solvers (Malouff, 2011). Oftentimes, it seems as though students cannot discern what the problem is asking because they are either too concerned with the math involved or they are unable to simplify the problem down to its base components (Fredish, 2005).

The difference between novice problem solvers and expert problem solvers, regardless of field, includes the principles utilized by the problem solvers. Marshall, in studying expert and novice accountants, found that Chi, Feltovich and Glaser's claim that the differences between novices and experts exists in the principles utilized in problem solving does not necessarily hold true (Marshall, 2002, and Chi, Feltovich and Glaser, 1981). Marshall found that both novices, undergraduate accounting students, and experts, professors and practicing accountants, utilized the same principles to solve the given problem. He contends that it is the experience the experts have at employing the principles that contributes to the discrepancy in the performance of novices when compared with experts. Familiarity with the principles at hand, as well as practice, aids in developing problem solving skills. Novices have not had the time to gain familiarity.

In a review of research into how problem solving can be best taught, Fuller cites several studies as he creates a road map towards developing expert problem solvers (Fuller, 1982). These studies support Marshall's notion of familiarity from before. Fuller states, citing Chi, Feltovich and Glaser (1981) and Larkin, McDermott, Simon and Simon (1980), that experts have the same tools as novices, but they approach the problem less from a solution-centric focus and more from a logical progression (Fuller, 1982, Chi, Feltovich, and Glaser, 1981, and Larkin, McDermott, Simon and Simon, 1980). Novices attempt to jump straight to the parts of the problem that would produce a solution. The manner in which experts organize their tools enables them to experience better results in physics problem solving. Lastly, he describes protocol for developing novice problem solvers in order to nurture them towards becoming expert problem solvers. He cites Reif, Larkin and Brackett (1976), stating that students should step back and make sure they understand the problem. Jumping right into the problem prevents students from understanding what the problem is asking. Students then need to identify guiding principles that will aid in solving the problem. The third part of the protocol is the part that students want to do first, the substitution of numbers into known relationships. Lastly, students should review their work. “Does the result make sense?” (Reif, Larkin, and Brackett, 1976, Fuller, 1982). This is another part that students routinely ignore. They are satisfied having achieved a result, sometimes not even realizing that a simple check could inform them of errors within their result.

Traditional physics classrooms involve lecturing and examples. However, this is not the best way of instructing students how to problem-solve, as it does not help them develop a conceptual understanding of problems but merely reinforces a more plug-and-chug methodology among the students (Boller, 1999). In Boller’s compilation of studies in the methods of unusual physics classrooms he compared pre- and post- course Force Concept Inventory (FCI) scores using the Hake factor, a measurement of gains over the time period of the course. Peer instruction had the greatest Hake factor, about 3.5 times greater than traditional instruction (Boller, 1999). Groups can be constructed in a variety of methods. In general it does not matter whether groups are constructed based on learning style (Westbrook, 2011), but having little variance in learning styles within a group can impede group efficiency (Lamm et.al., 2012). In a study on problem solving groups with semi-expert leadership, science students saw noticeable gains in the critical thinking associated with problem solving, especially among the female students involved (Quitadamo, Brahler, and Crouch, 2009). The semi-experts were group leaders who had previously taken the course. These group leaders were able to bridge the gap between students and instructors, aiding the current students in their development.

In general, students taking a first year physics course exhibit characteristics of novice problem solvers when it comes to solving physics problems. They rush into problems and immediately seek an answer instead of concentrating on the understanding and concepts necessary for finding valid solutions. They lack awareness and experience that would tell them whether their answers make sense. Peer groups have had positive effects on the problem solving skills of novice problem solvers. Leadership is useful when using group problem solving. These are the important ideas that have contributed to the notion of viewing the impact that a more group-centered problem solving method will have on student performance on problem-solving assessments.

METHODOLOGY

First year physics students in my Honors Physics course exhibit characteristics of novice problem solvers. They jump into problems seeking an answer immediately and lack the patience and focus to determine what the problem is asking first. Boller (1999) reported the greatest gains in physics problem solving through the utilization of peer instruction. My study focused on determining the impact of peer-led group problem solving on the problem solving skills of high school students in their first physics class. The research methodology for this project received an exemption by Montana State University’s Institutional Review Board.

The participants in the study were the students in the two Honors Physics sections in the Augusta Preparatory Day School Upper School. Honors Physics fulfills the physical science graduation requirement and is a more algebra- and trigonometry-based option for the requirement than Conceptual Physics, the other main option for the requirement. A total of 23 students were in the two classes of the year-long course for this academic year. The course covered mechanics in the fall semester, and thermodynamics, electricity and magnetism, optics, relativity, and nuclear and quantum physics in the spring semester. The course is traditionally slightly male dominated, although this year 10 of the 23 students are female, an insignificant deviation from the distribution within the student body, given the small sample size. Approximately 40% of the participants are considered ethnically diverse, in contrast to 24% of the student body. The students enrolled in Honors Physics are generally considered to be the high-achieving students as the course requires a teacher recommendation and instructor permission prior to enrollment.

To examine the effects of peer groups on the problem solving skillsets of first-year physics students, my two Honors Physics classes engaged in different problem solving methods for the five chapters of the electricity and magnetism unit. For the year, the two classes were treated as one; they cover the same material at the same pace, and have the same assignments and problem solving assessments. The problem solving assessments examine students' problem solving abilities as they pertain to the material at hand. Success on a problem solving assessment shows the use of a conceptual understanding and a knowledge of applicable physics relationships to solve a problem. Lower scores on these assessments mean that a student was less able to apply conceptual understanding appropriately to the question at hand. Those students were unable to first interpret the problem and then take the appropriate steps to find a solution to the problem. Using results on these assessments, I determined each class' relative performance and saw whether one class was having more or less success relative to the other. Prior to the start of the treatment, I accrued a solid set of data detailing the relative problem solving skillset of each class. Through the units on mechanics and thermodynamics, one section of Honors Physics had consistently performed 6.5% better on problem solving assessments than the other section ($t(22) = 5.245$, $p<0.005$).

The course progressed in a similar manner to its currently established pattern. Each chapter was split into sections based on topic. Each section usually took two in-class days. Approximately half of the first day involved a discussion of new material and any relevant equations. The remaining day and a half involved problem solving for that section. During that time, around five problems were solved and explained. The differences between the treatment and non-treatment classes occurred during the problem solving sessions. For the non-treatment section, I continued to lead the class in solving those problems through the traditional teacher-led method. I went over each problem, discussed pertinent information and set up the problem so that it could be solved, paying attention to the concepts important to the problem. For the treatment class of Honors Physics, the second half of the introduction day was used to demonstrate how the new concepts and relationships could be applied to problem solving by solving one or two problems. The remaining problems for the section were given to the class to solve on the second day for the section. Students were split into groups of three to four members and given a protocol to use in solving the assigned problems.

Intervention

The protocol employed for the group problem solving sessions involved all members working together to develop an understanding of the problem and create a method of obtaining a solution to the problem. The group could not just provide an answer, but must also be able to explain each step carried out in creating its solution. Each day, one member of each group was assigned the role of leader and time keeper, with that role rotating throughout the unit. The leader was charged with reading the problem and keeping the group on task. The group leader was to instruct the group to spend two minutes thinking about the problem after it was read. Students were encouraged to remain silent during that time so that each member could think and be engaged in the problem-solving process. After the thinking time had passed, the leader was to ask the group for a general idea of the problem: what kind of problem had been assigned, what was the unknown, and what principles were involved in the problem? Each day concepts that might be of importance to that day's problem solving were written on the board as well as on the protocol handed to the group so that students had a framework to guide their thoughts as they attempted to answer the leader's questions.

After the group came to a consensus, the group was to work towards determining how to apply the concepts from the unit to solve the problem. At this point in the protocol, the group leader was to call over the instructor to make sure they fully understood the problem and had appropriately applied concepts to the problem before attempting to find their solution. Upon receiving approval, the group was to work towards arriving at a solution and answer. If approval was not immediately given, students were to receive some additional guiding questions to help the group towards the requisite understanding. Once a solution had been found, each group was to get instructor permission before continuing with the next problem to ensure that the finished problem was understood. Additionally, during the group problem solving, I was to be present, moving around the classroom to monitor each group's progress as well as to answer any questions and give advice if necessary. At the end of the period, solutions were presented to the class so each group could check their work. A sample protocol handout can be found in Appendix A.

Data Collection Methods

The effectiveness of the group problem solving treatment was assessed throughout the electricity and magnetism unit by using a variety of data sources. Table 1 gives the data sources used to answer the focus question and sub-questions.

Table 1
Data Triangulation Matrix

Questions	Data Sources		
Focus: What is the impact of peer grouping during problem solving sessions on the problem solving skills of high school physics students?	Problem Solving Assessments and Concepts Quizzes	Post-Treatment Survey and Student Interviews	Teacher Observations
Sub-Question 1: What problem solving skills and conceptual understanding do students gain from their peers through group study that they do not gain through a traditional classroom setting?	Problem Solving Assessments and Previous Assessment Data	Concepts Quizzes	Teacher Observations
Sub-Question 2: Will the dynamic of collaborative problem solving sessions influence students' classroom engagement?	Teacher Observations	Post-Treatment Survey	Student Interviews
Sub-Question 3: Will the group problem solving exercises affect students' views concerning the study of physics?	Teacher Observations	Post-Treatment Survey	Student Interviews

Throughout the treatment period, both the treatment and non-treatment classes were observed for their classroom engagement and how well they responded to inquiries concerning the classroom problem solving. Both classes were given formative assessments to gauge their conceptual understanding of the material for each section. A sample series of multiple choice questions measuring conceptual understanding can be found in Appendix B. At the conclusion of each chapter, the same problem solving assessment was given to each class. The results of the problem solving assessments were compared between the two classes, treatment against non-treatment. Data gathered throughout the first half of the year, up until the start of the treatment, served as a baseline for the two classes' respective relative performances. The relative performance of the two classes during the treatment was compared to the baseline performance set during the fall semester. A sample problem solving assessment can be found in Appendix C. Following the completion of the electricity and magnetism unit, students in both classes were given a survey concerning their problem solving and their conceptual understanding of the material covered during the seven week unit. The survey can be found in Appendix D. Students were also given a small notecard, requesting permission to potentially be selected for an interview; of the affirmative answers, students were grouped by section and selected at random from those groupings. The sections were the treatment section and the comparison section. I interviewed the selected students from each of the two sections in order to gain a more in-depth perception of how they view problem solving in physics and what they feel has been the greatest benefit or detriment of the new methodology on their physics problem solving skillset. The general interview protocol can be found in Appendix E.

Timeline

The timeline for the treatment was a seven week period beginning on January 22^{nd}, 2015. The treatment encompassed the entire electricity and magnetism unit of Honors Physics. Four problem solving assessments were given, one at the conclusion of each of the four chapters of the electricity and magnetism unit. From January 22^{nd} through January 30^{th}, the course studied electric fields and electrostatic forces, a period of six class days. The following chapter on electric potential took place from February 2^{nd} through February 11^{th}, a period of eight class days. From February 17^{th} through March 4^{th}, a period of 12 class days, Honors Physics studied the chapter on circuits and circuit elements. Lastly, the chapters covering magnetism were studied from March 5^{th} through March 18^{th}, a period of 10 class days. A daily schedule of the treatment period can be seen in Table 2 in Appendix F.

DATA AND ANALYSIS

The focus of the action research project was to examine the impact of peer grouping during in-class problem solving sessions on the physics problem solving skills of high school physics students. Students in the treatment and comparison sections were given four problem solving performance assessments during the unit on electricity and magnetism. They were also periodically presented with formative concept quizzes to gauge understanding of the material covered during the preceding days. Observations were made concerning the group dynamics of the treatment sections. At the conclusion of the unit, the students were surveyed and three students from each section were interviewed concerning physics, the Honors Physics course and problem solving within the course.

Impact on Problem Solving Skills and Conceptual Understanding

The first sub-question for the action research was "what problem solving skills and conceptual understanding do students gain from their peers through group study that they do not gain through a traditional classroom setting?" During the treatment it appeared as though there was a small improvement on the problem solving skills of the treatment group for in class problem solving sessions when compared to the skills of their peers in the comparison group that engaged in teacher-led problem solving sessions. Prior to the treatment, the comparison group students outperformed their treatment group counterparts by an average of 6.54% on problem solving-based performance assessments (86.95±2.06 for comparison against 81.61±2.86 for treatment), only once averaging less than the treatment group on a total of twelve assessments. These differences ranged from -1.3% to 15.8%, with the median assessment 6.6% above that of the treatment group. During the treatment, however, four problem solving-based performance assessments were administered to both sections. The difference between the two sections on those four assessments, cumulatively, was 0.15% (85.75±4.00 for comparison against 85.88±6.65 for treatment). These differences ranged from -4.1% to 5.6%, with the treatment group scoring better as a class on two of the four assessments. Even with the high variance for the treatment problem solving assessments, the comparison section showed only a small difference between pre-treatment and the treatment's electricity and magnetism assessments ($t(14) = 0.573$, $p>0.5$), while the treatment section showed some growth during the treatment ($t(14) = 1.247$, $p<0.3$). Figure 1 shows the relative performance of the comparison and treatment sections on problem solving assessments.

Figure 2 shows the average assessment scores by section for the periods preceding the treatment as well as during the treatment.

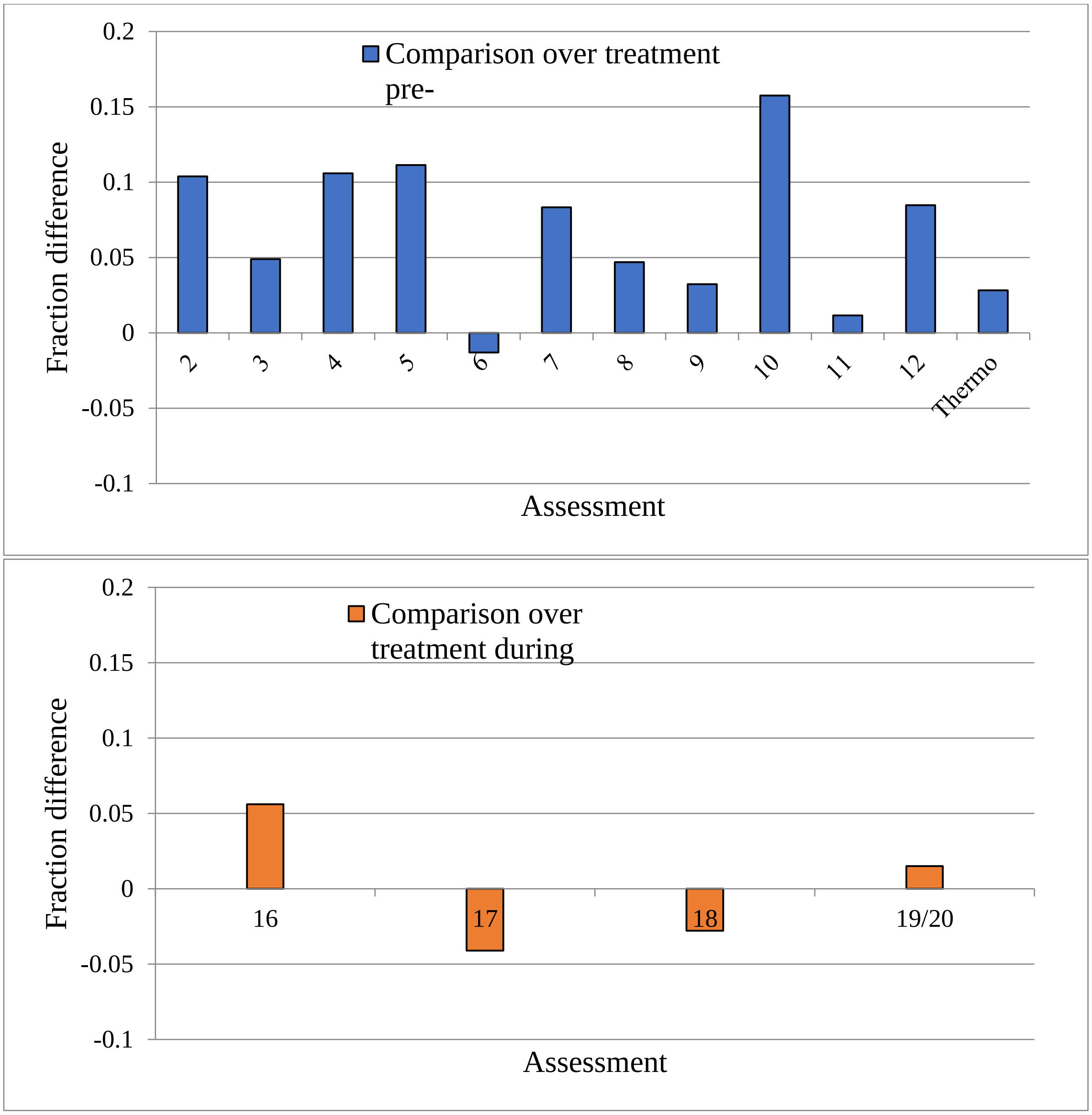

Figure 1. Relative performance of comparison and treatment sections, prior to the treatment (above) and during the treatment (below), ($N_{treatment}$=10, $N_{comparison}$=13).

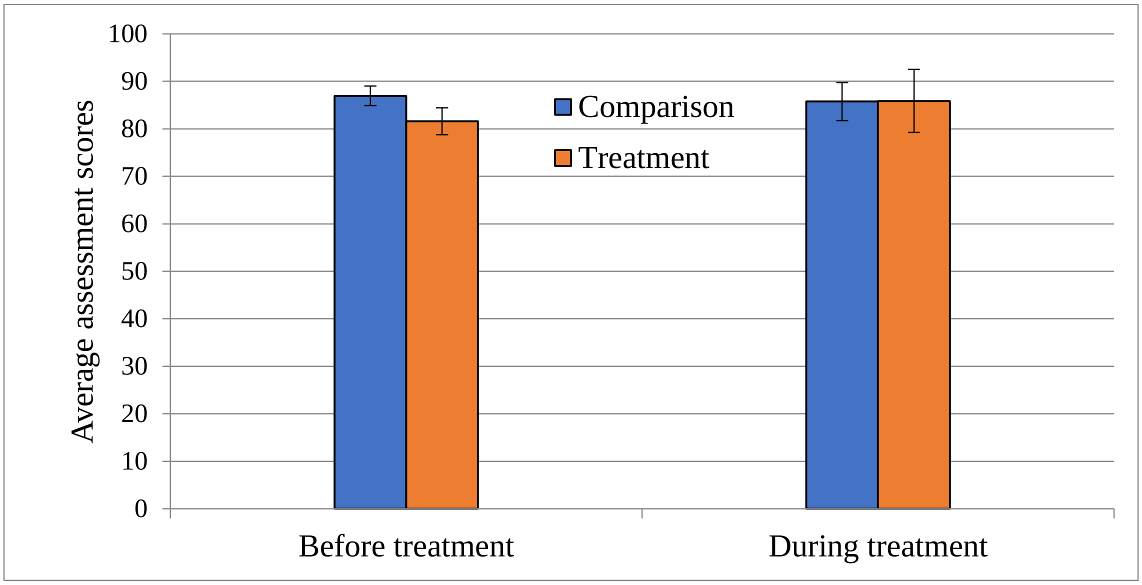

Figure 2. Average assessment scores by section, ($N_{treatment}$=10, $N_{comparison}$=13).

Additionally, the first sub-question attempted to see what impact on conceptual understanding students gain from their peers through group study that they do not gain through a traditional classroom setting. It did not appear as though any gains were made conceptually through the use of peer grouping in the treatment section. On formative assessments, the non-treatment section regularly out-performed their treatment section counterparts, averaging over 27% better on small four to five question concept check assessments, as seen in Table 2 and Figures 2 and 3 below.

Table 2
Formative Assessment Participants and Points Earned by Section

		Treatment Section		Comparison Section	
Assessment	Questions	Participants	Total Points	Participants	Total Points
16a	4	8	15	13	25
16b	4	9	16	13	30
17a	4	10	19	13	39
17b	2	8	8	12	12
18a	5	9	20	13	39
19a	5	9	19	13	39
19b	5	10	20	13	33

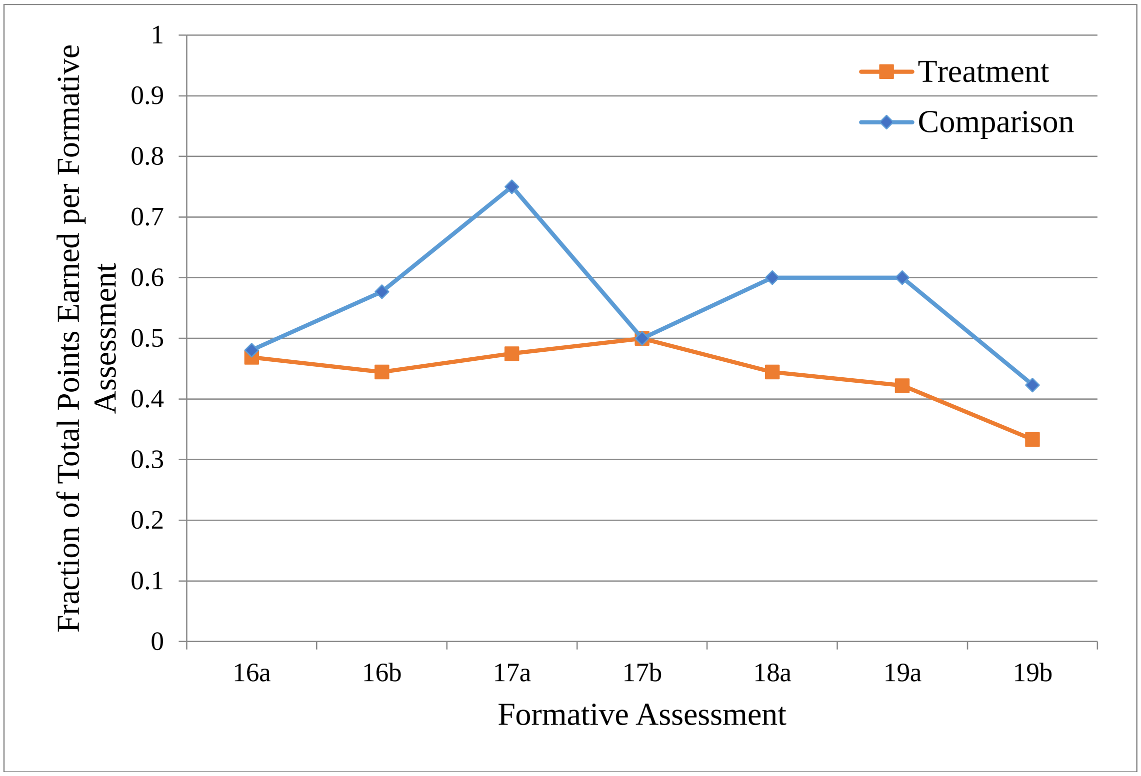

Figure 3. Fraction of total points possible earned by section on formative assessments.

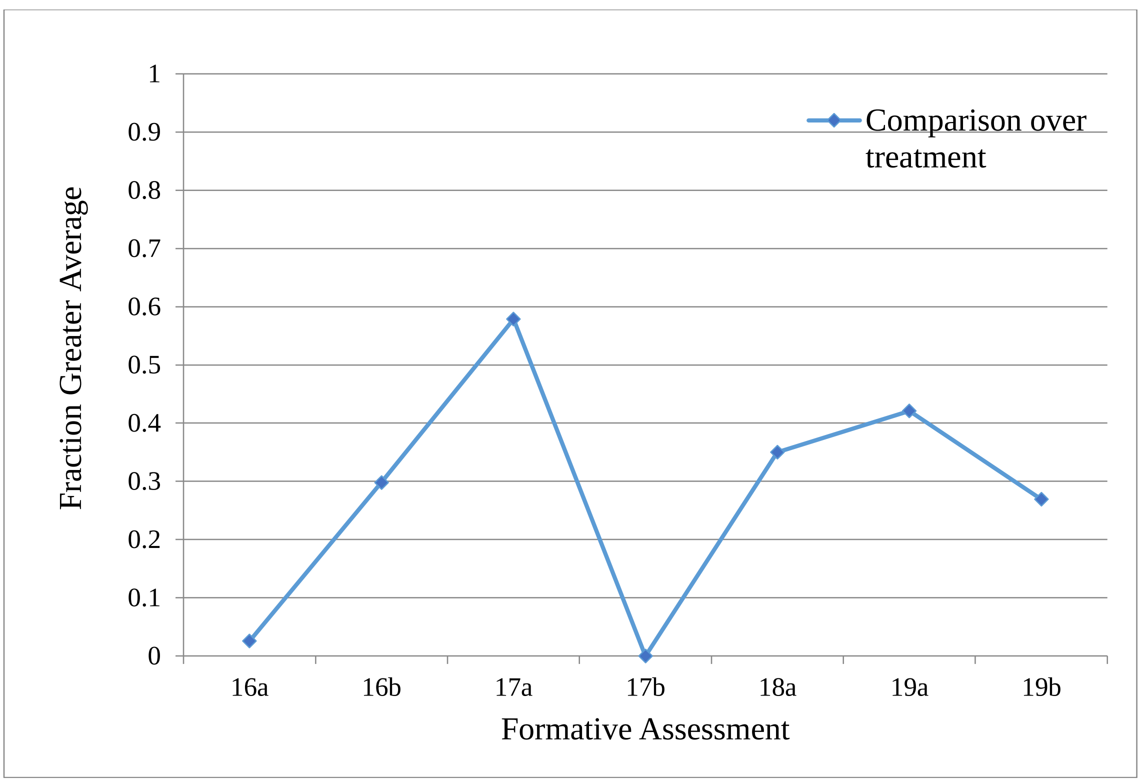

Figure 4. Fraction higher average score of comparison section versus treatment section.

Additionally, this gap did not narrow as the treatment progressed. It may be that this was inconclusive, as on multiple occasions the non-treatment section had a few students score perfect or nearly perfect, whereas the treatment section rarely recorded a perfect score on a formative assessment. It may have been that the sections did equally well when accounting for those outliers; however, the data was not procured in a way to isolate those outliers.

Influence on Classroom Engagement

The second sub-question was "will the dynamic of collaborative problem solving sessions influence students' classroom engagement?" The information gathered for this question was inconclusive. During interviews, students indicated that they feel more engaged during different types of problem solving exercises. Of the three students interviewed from the treatment section, two students felt more engaged during group exercises, with the other feeling as though group or individual work fostered the greatest engagement during problem solving exercises. Of the three students interviewed from the comparison section, one felt their engagement was better by herself because "working in a group… [would force her to] ask them what they're thinking and tell them what [she's] thinking so it's not purely working on the problem anymore", one preferred teacher-led problem solving exercises, and the last felt that individual and group work gave the greatest engagement. These responses corresponded to a trend observed during problem solving sessions. In groups involving five of the ten students in the treatment section, there was a tendency for the group to work as individuals and then check back after everyone had a chance to work on their own for a bit. These individuals left their mark on their groups regardless of the rest of the group composition. The last ambiguous suggestion as to whether collaborative problem solving sessions had an influence on classroom engagement comes from the post-treatment survey. The post- treatment survey can be found in Appendix D. Data from the surveys can be found in Table 2 below.

Table 3
Post-Treatment Survey Responses

	Number of Respondents from Treatment Section						Number of Respondents from Comparison Section				
Response	0	1	2	3	4		0	1	2	3	4
QA1	0	0	1	3	4		0	0	1	7	3
QA2	0	0	5	1	2		0	1	7	2	1
QA3	0	1	5	1	1		1	2	1	4	3
QA4	0	6	1	1	0		3	6	1	1	0
QA5	1	2	5	0	0		2	3	4	1	1
Note. 0=Not at all, 1=Rarely, 2=Sometimes, 3=Frequently, 4=Always. ($N_{treatment}$=8, $N_{comparison}$=11)											
QB1	0	1	4	2	1		1	2	2	5	1
QB2	4	2	1	1	0		3	2	1	5	0
QB3	1	0	0	2	4		0	0	1	2	8
QB4	0	0	0	2	6		0	1	0	6	4
QB5	1	0	2	1	4		0	1	2	6	2
QB6	0	0	2	1	5		0	1	1	5	4
QB7	0	1	1	4	2		1	1	3	2	4

Note. 0=Strongly disagree, 1=Somewhat disagree, 2=Neither agree nor disagree, 3=Somewhat agree, 4=Strongly agree.
($N_{treatment}$=8, $N_{comparison}$=11)

QA1-QA3 concerned how students worked: A1 was independent work, A2 was work with classmates, and A3 was reliance on teacher help. For all three, only one student responded “not at all” for any, and that was for teacher help. Few students, between both the treatment and comparison sections, even responded “rarely”; in total, only 8.8% of responses showed infrequent to no use of one of the three resources available. Students, through the interviews, displayed a preference for various methods when problem solving; however, in general, they are not averse to using all at their disposal.

Views Concerning the Study of Physics

The third sub-question was "will the group problem solving exercises affect students' views concerning the study of physics?" The treatment did not have a discernible effect upon student views. During the post-treatment survey, students were asked to give value judgment to the statement "Physics problem solving is a beneficial component of a high school science education." In the non-treatment section, ten of the eleven polled students responded with "somewhat agree" or "strongly agree", with the last student responding "neither agree nor disagree". In the treatment section, seven of the eight polled students responded with "somewhat agree" or "strongly agree", with the last student responding with "strongly disagree". Across both sections, the student views mirrored each other, regardless of how problem solving was being conducted in the classroom. Interestingly, a lot of similar trends were found in some of the other survey questions. For example, in general, when prompted with "I enjoy working with my classmates and getting their opinions and viewpoints", the non-treatment section had seven of eleven responses of "sometimes", while the treatment section had five of eight responses of "sometimes". Similarly, when prompted "I enjoy physics problem solving", the non-treatment section had three responses of either "somewhat disagree" or "neither agree nor disagree", with six of the eleven polled students responding "somewhat agree"; the treatment section had three responses of "strongly disagree" or "neither agree nor disagree", with four of the eight polled students responding "strongly agree". While the degrees of agreement varied, in general, the majority of students in both sections takes some enjoyment out of physics problem solving and recognizes its importance as part of their high school education.

During interviews, the questions “how do you feel about the study of physics?” and “should this course be a requirement to graduate?” were posed. All six interviewees, regardless of section, responded affirmatively, that they felt the course was a good course to require. Two interviewees mentioned that physics itself should be required, not necessarily the level of the course, as they are in an honors-level course. Other comments in responding to those questions included that taking Honors Physics “stimulates thinking”, “is a challenge, even though [she’s] not planning on studying it in the future” and “it teaches [the student] how to think”. Because of these responses, it appeared that the partaking in group problem solving exercises did not noticeably impact students’ feelings concerning the course in general.

INTERPRETATION AND CONCLUSION

The purpose of this action research project was to examine the impact group problem solving would have on the problem solving skills of first year physics students. The project also sought to examine what impact the group problem solving might have had on the conceptual understanding of the material for students and whether the collaboration would foster increased engagement in the physics classroom. The project took a number of the problems traditionally solved in class with the teacher leading and allowed the students in the treatment section to work through those problems in small groups.

One of the biggest findings during the action research project was the observation during group problem solving sessions that students sought out the answers and were more concerned with checking their answer as opposed to taking their time, asking questions of each other, and seeking an understanding of the problem. The students were caught up in attempting to find the answer and make sure that it was correct instead of worrying whether their methodology was appropriate and whether their final answer made sense, regardless of its accuracy. This was one of the main differences cited by Fuller in his discussion of novice problem solvers and expert problem solvers (Fuller, 1982). Interestingly, while problem solving assessments appeared to show improvement among the treatment group, their conceptual understanding of the material did not see similar gains, as evidenced by the formative assessments. This indicates that while students were improving at procuring an answer, their solution as a whole did not necessarily demonstrate a full conceptual understanding.

The next biggest finding came in gathering students views concerning the treatment. These views were gathered both through classroom observations as well as through the end of treatment interviews carried out in both the treatment and non-treatment sections. Students had highly varied responses to the treatment. When the sections were selected, there were students in both that were thrilled as well as students that were disappointed, for varying reasons. Different students have greater classroom engagement under different circumstances. For some, working in a group or by themselves provided the highest level of engagement. For others, it was preferable to have the teacher lead problem solving exercises. Boller felt that community colleges should focus on one of a few non-traditional models he examined and make it work for their system (Boller, 1999). However, at least in the high school setting where the treatment took place, students responded differently to different methods and expressed different preferences, whether they were non-traditional or traditional. Because the students were aware of their own preferences, they responded accordingly to the news of which section was the treatment versus which was the non-treatment. Students who enjoyed or appreciated their level of engagement during the treatment period because of the group work asked for more of the in-class problem solving exercises to be carried out in a group, just because they experienced their increased levels of engagement.

Moving forward, there are changes that would have to be made for the intervention. The lack of consistency among the groups in how rigorously they approached the group problem-solving protocol would have to be addressed. While students appreciated the hints given on the protocol sheets in addition to the abstract version of the notes and equations for the section, they were less concerned with how the protocol wanted them to approach the problem solving. It is possible that an alternative protocol could be utilized in a future treatment. The protocol would still have the expressions and hints for the problems to be solved. However, after solving each problem, each group would be tasked with coming up with an alternative way of asking the question. The goal would be for students to understand the principles behind the question enough so that they could create a question that would challenge another group to think through the problem and have to work towards finding a solution.

Lastly, as previously mentioned, the conceptual understanding of the material needs to receive a greater stress; both the treatment and non-treatment sections did not do as well on formative assessments as they probably should have been doing. Future work towards the intervention would include a greater conceptual component as well as examining the effects on the non-treatment section. This was brought up by two students during the interview process. One suggested one change in how problem solving was run in class would be to spend more time on the conceptual background of each problem.

The other commented, when discussing his problem solving skills, that the simple act of solving more problems, no matter the format, bred familiarity with the material that helped him as the course progressed. This corresponds to Marshall's claim that experience is necessary in order to appropriately utilize the problem solving skills and conceptual knowledge that novices have already gained (Marshall, 2002). The gains that were seen in the treatment section this time around would conceivably be met with an increase in the performances on problem-solving assessments by the non-treatment section when they engaged in a more varied approach to their in-class problem solving, including group work.

VALUE

The process of this action research project has convinced me that professional growth is an ongoing process. Regardless of what is occurring on in the classroom, and how well it appears to be going, there is always the possibility that something could be done better or that there is some aspect of my teaching and the learning taking place in the classroom that is missing. Especially because I have usually utilized a more traditional method of teaching in the classroom, the more frequent use of group work was a change from my previous classroom methods. Even though some students did not see the same perceived benefit as did others, the goal is to provide the greatest learning opportunity to as many students as possible. I want to develop as many novice physics problem solvers during their first-year course as possible.

I am going to need to continually examine what I do in the classroom and determine if there are better ways to develop problem solvers. There are many students who come into Honors Physics wanting to love the material, but they struggle with the problem solving component and are somewhat turned off the material because of it. They do not get the same appreciation of the material as other, higher-achieving students in the problem solving component because they struggle to comprehend the same breadth of material as do their peers. It will be important to start more varied methods of problem solving at the beginning of the year and to be sure to explain to students the reasons for problem solving. My students this year were more receptive to the efforts of the action research project when they were informed what it was, why it was being carried out, and what I hoped to see in it. Even if it would not necessarily be to their benefit, they were willing to try more group work, or allow the other section to utilize another method, to see if it could help in the future.   The one part of the intervention that needs to be better discussed with the students is why problem solving is important and what methods expert problem solvers employ so that they are successful. Because of the receptive nature of my students, adding a discussion of the merits of a successful problem solver would be a good starting point for continuing to examine how to better improve the problem solving skills of first year physics students.

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APPENDICES

APPENDIX A

SAMPLE PROTOCOL FOR GROUP PROBLEM SOLVING

Chapter 16. Section A. Charge and Electrostatic Forces
Group problems: 3, 11, 17, 21.

Concepts and equations to remember:

Negative charge comes from electrons, positive charge is the absence of electrons.

$e = 1.6x10^{-19}\ C$ $\qquad$ $\|F_E\| = \frac{k\|q_1\|\|q_2\|}{r^2}$ $\qquad$ $k = 8.99x10^{9}\ \frac{Nm^2}{C^2}$

Like charges repel, opposite charges attract.

Protocol:

1. Group leader read the problem. Give 2 full minutes for all members to think over the problem and any concepts that might apply to the problem.

2. Poll the group. What kind of problem is this? What is unknown, what is known? What principles are applicable in this instance?

3. Come up with a consensus about how to progress in the problem. What concepts are you going to apply, and how? DO NOT progress beyond that point yet. Call over the instructor and confirm your plan of action.

4. If approval is given, work towards finding a solution and/or answer. Make sure you show work – that is a hallmark of a solution, as opposed to just supplying an answer.

5. Check the answer to your solution in the back of the textbook. If it is correct, call over the instructor to check over your solution. If incorrect, look over your solution and see if you can find your error.

6. Spend about 10 minutes on each problem. If you are having difficulties, ask your instructor for some guidance.

7. Solutions will be presented at the end of the class.

Notes on each problem that might be helpful:

3. electrons have charge -e $\qquad$ 11. $q_1 = q_2$ $\qquad$ 17. what is r compared to r_o?

21. forces are vectors – they have magnitude AND direction

APPENDIX B

SAMPLE CONCEPTUAL UNDERSTANDING QUESTIONS

16A.

1. Two charged particles attract each other with a force of magnitude **F** acting on each. If the charge of one is doubled and the distance separating the particles is also doubled, the force acting on each of the two particles has magnitude

a. **F**/2
b. **F**/4
c. F
d. 2**F**
e. 4**F**
f. None of the above

2. Which of the statements comparing electric and gravitational forces is correct?

a. The direction of the electric force exerted by one point particle on another is always the same as the direction of the gravitational force exerted by that particle on the other.
b. The electric and gravitational forces exerted by two particles on one another are inversely proportional to the separation of the particles.
c. The electric force exerted by one planet on another is typically stronger than the gravitational force exerted by that same planet on the other.
d. None of the above

3. An α particle (charge +2e and mass $4m_p$) is on a collision course with a proton (charge +e and mass m_p). Assume that no forces act other than the electrical repulsion. Which one of these statements about the accelerations of the two particles is true?

a. $\mathbf{a}_\alpha = \mathbf{a}_p$
b. $\mathbf{a}_\alpha = 2\mathbf{a}_p$
c. $\mathbf{a}_\alpha = 4\mathbf{a}_p$
d. $2\mathbf{a}_\alpha = \mathbf{a}_p$
e. $4\mathbf{a}_\alpha = \mathbf{a}_p$
f. $\mathbf{a}_\alpha = -\mathbf{a}_p$
g. $\mathbf{a}_\alpha = -2\mathbf{a}_p$
h. $\mathbf{a}_\alpha = -4\mathbf{a}_p$
i. $-2\mathbf{a}_\alpha = \mathbf{a}_p$
j. $-4\mathbf{a}_\alpha = \mathbf{a}_p$

APPENDIX C

SAMPLE PROBLEM SOLVING ASSESSMENT

Honors Physics Chapter 16 Assessment
Name and Pledged

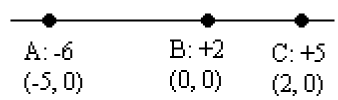
Unless otherwise stated, values are in SI units (distances in meters, charges in coulombs).

1. You are given 3 identical metal spheres. Follow the directions below, and notate the values of the charges on each sphere following each step in the table.

a. A, B touched, removed.
b. A, C touched, removed.
c. A, B, C touched, removed.

	Sphere A	Sphere B	Sphere C
Initial	0	12q	-18q
Step a			
Step b			
Step c			

2. At right is an arrangement of point charges fixed in space and their locations on the x-axis. Assume charge values are multiples of e.



a. Determine the direction of the net electrostatic force on each of the particles.
b. Point charge A is removed from the arrangement. Determine the location along the x-axis where there is no net electric field.

3. Calculate the total positive charge contained in one mole of fluorine (F_2).

4. Three point charges are arranged according to the data below. Determine the magnitude and direction of the net electrostatic force on point charge C.

A: (0,0) +4e
B: (5,0) +10e
C: (0,5) - 1e

5. A charged plate creates a uniform electric field of magnitude 10^5 N/C directed vertically downwards towards the plate. A charged particle of mass 1μg is suspended above the plate.

a. What is the sign of the charge on the particle? Explain.
b. What is the value of the charge of the particle?

6. A bizarrely shaped three dimensional object has 6 faces of varying areas. It is subjected to an electric field that penetrates each side orthogonally through some crazy situation. Based off the data below, determine the net charged enclosed in the three dimensional object. Areas are measured in m^2.

Face A: area 1, field 3N/C outward
Face B: area 5, field 1N/C inward
Face C: area 3, field 3N/C outward
Face D: area 4, field 1N/C inward
Face E: area 6, field 3N/C inward
Face F: area 2, field 5N/C outward

APPENDIX D

POST-TREATMENT STUDENT SURVEY

Participation in this survey is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at any time. Your participation or non-participation will not affect your grade or class standing. Please do not write your name on the document; your responses will not be correlated to any name.

Please respond to the following questions using the following scoring:

0: Not at all 1: Rarely 2: Sometimes 3: Frequently 4: Always

1. I take responsibility for my studies and enjoy working independently.	
2. I enjoy working with my classmates and getting their opinions and viewpoints.	
3. I rely on my teacher to help me throughout the course.	
4. I read the textbook regardless of whether I have been instructed to specifically read certain sections.	
5. I look over unassigned problems on my own, including sample problems in the text.	

For the following questions, please use the new scoring mechanic below:

0: Strongly disagree	1: Somewhat disagree	2: Neither agree nor disagree	3: Somewhat agree	4: Strongly agree

1. Physics problem solving requires more math knowledge than physics understanding.	
2. Physics problem solving requires memorization.	
3. Physics problem solving is a beneficial component of a high school science education.	
4. Physics problem solving helps with the conceptual understanding of the topics covered in class.	
5. I enjoy physics problem solving.	
6. I enjoy physics class.	
7. I enjoy physics laboratory exercises.	

If you have any comments to any of the previous questions, please respond on the back. Remember, this is an anonymous survey; your name should not appear anywhere on the document.

APPENDIX E

GENERAL STUDENT INTERVIEW PROTOCOL

These questions will be asked during interviews with students from both the treatment and non-treatment sections.

1. How do you feel you are as a physics problem solver?

2. From the beginning of the year until the end of the first semester, how do you feel your physics problem solving skills have changed, if at all?

3. During the unit on electricity and magnetism, how do you feel your physics problem solving skills have changed, if at all?

4. What has affected your problem solving skills in this course over those two periods (fall, electricity and magnetism)?

5. If you were to make any changes to the problem solving component to this course, what would those changes be? Why would you make those changes?

6. Outside of class, when completing your homework or studying, how do you use your classmates? What role do they serve?

7. How do you feel about the study of physics? Should this course be a requirement to graduate?

These questions will be for interviewees from the treatment class.

1. What are your thoughts about the change in the in-class problem solving methods?

2. (Regardless of the previous answer…) What are your feelings about the protocol used for the group problem solving? Were they helpful or detrimental to the group?

3. What were your feelings about your group? What effect did your group have on your problem solving skills? Which is preferable: working in a group, working alone, or having teacher-led problem solving? In which method would your engagement be highest?

These questions will be for interviewees from the non-treatment class.

1. What are your thoughts about how in-class problem solving takes place (with the teacher leading)?

2. Which is preferable: working in a group, working alone, or having teacher-led problem solving? In which method would your engagement be highest?

APPENDIX F

DAILY SCHEDULE OF TREATMENT PERIOD

Table 4.
Daily Schedule of Treatment Period

Day (HW due)	Topics/items
Jan. 22	Day 1, Sec. A Ch. 16 – material + teacher probs. (to 16.3)
Jan. 26	Day 2, Sec. A Ch. 16 – group probs. + formative
Jan. 27 (to 20)	Day 1 Sec. B Ch. 16 – material + teacher probs. (to end)
Jan. 28	Day 2 Sec. B Ch. 16 – group probs. + formative
Jan. 29	PHET charges/field lines – intro. to equipotential
Jan. 30 (28-64)	Problem solving assessment
Feb. 2	Day 1, Sec. A Ch. 17 – material + teacher probs. (to 17.2)
Feb. 3	Day 2, Sec. A Ch. 17 – group probs. + formative
Feb. 4 (to 26)	Day 1, Sec. B Ch. 17 – material + teacher probs. (to 17.4)
Feb. 5	Day 2, Sec. B Ch. 17 – group probs. + formative
Feb. 6 (to 52)	Day 1, Sec. C Ch. 17 – material + teacher probs. (to end)
Feb. 9	Day 2, Sec. C Ch. 17 – group probs. + formative
Feb. 10	Capacitor lab exercise
Feb. 11 (58-82)	Problem solving assessment
Feb. 12	Half day – work on capacitor lab exercise
Feb. 17	Day 1, Sec. A Ch. 18 – material + teacher probs. (to 18.3)
Feb. 18	Day 2, Sec. A Ch. 18 – group probs. + formative
Feb. 19 (to 16)	Day 1 Sec. B Ch. 18 – material + teacher probs. (to 18.4)
Feb. 20	Day 2, Sec. B Ch. 18 – group probs. + formative
Feb. 23 (to 26)	Day 1 Sec. C Ch. 18 – material + teacher probs. (to 18.7)
Feb. 24	Day 2 Sec. C Ch. 18 – group probs.
Feb. 25	Day 3 Sec. C Ch. 18 – group probs. + formative
Feb. 26 (to 60)	Day 1 Sec. D Ch. 18 – material + teacher probs. (to end)
Feb. 27	Day 2 Sec. D Ch. 18 – group probs. + formative
Mar. 2	Circuits lab day 1
Mar. 3	Circuits lab day 2
Mar. 4 (to end, a few RC)	Problem solving assessment
Mar. 5	Day 1 Sec. A Ch. 19 – material + teacher probs. (to 19.5)
Mar. 6	Day 2 Sec. A Ch. 19 – group probs.
Mar. 9	Day 3 Sec. A Ch. 19 – group probs. + formative
Mar. 10 (to 40)	Day 1 Sec. B Ch. 19 – material + teacher probs. (to end)
Mar. 11	Day 2 Sec. B Ch. 19 – group probs. + formative
Mar. 12 (to end of 19)	Day 1 Sec. A Ch. 20 – material + teacher probs. (to 20.4)
Mar. 13	Day 2 Sec. A Ch. 20 – group probs.
Mar. 16	Day 3 Sec. A Ch. 20 – group probs. + formative
Mar. 17	PHET Faraday’s EM Lab
Mar. 18 (all of Ch. 20)	Problem solving assessment