Interactive-Engagement, Conceptual Change, and Self-Efficacy in a Direct Current Unit in a Secondary Physics Course

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Interactive-Engagement, Conceptual Change, and Self-Efficacy in a Direct Current Unit in a Secondary Physics Course.

by

Daniel M. Hosey

A thesis submitted to the Department of Education and Human Development of the State University of New York College at Brockport in partial fulfillment of the requirements for the degree of Masters of Science in Education

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Dany, I'm proud of your work! R.V.

7/30/08 Date

7/31/08 Date
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Abstract

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The interactive-engagement techniques of Peer Instruction and context rich problems were implemented in a secondary physics classroom. The study took place during a three-week direct current unit. The relationships between interactive-engagement, self-efficacy, and conceptual understanding are discussed. The role of gender is also considered. Student perspectives on Peer Instruction and context rich problems are reported and recommendations for implementing these teaching strategies are made.
Chapter One: Introduction

Introduction

Despite the best efforts of teachers, traditional teaching does little to change the conceptual understanding of introductory physics students. Many students who do well on traditional computational exams do poorly when given conceptual questions (Hake, 1998). Providing more practice problems does little to increase student conceptual understanding (Eunsook and Sung-Jae, 2003). Such performance directly contradicts the goals of most physics instructors who value abstract problem solving skills. Such poor performance is also surprising to most physics teachers who tend to view conceptual questions as much simpler than the computational questions.

The root of this contradiction may lie in the role of misconceptions in the way students learn (Harvard, 1987). Before students can accept new ideas about the way the world works they must first recognize their own ideas and systematically test them against new information. In a traditional, teacher-centered classroom, students have little time to examine their own ideas and assumptions. When faced with a new problem, students tend to fall back on their previously held conceptions, making it difficult to perform well on conceptual questions (Kikas, 2003).

When students examine their existing ideas, they learn better. Interactive-engagement instructional techniques such as cooperative learning (Johnson & Johnson, 1993) and Peer Instruction (Mazur, 1997) have been shown to increase student conceptual understanding (Hake, 1998). These techniques allow students to verbalize their conceptions and evaluate them. Physics Education Research (PER) has shown significant advantages of active learning strategies over passive lecture.

Student success has also been linked to student self-efficacy (Fencl & Sheel, 2005). Students who believe that they can succeed tend perform significantly better than students who do not believe they can succeed. This pattern sets up a sort of self-fulfilling prophecy where the attitudes of a student are just as important as the instruction he or she receives. As educators it is vital that we consider how our teaching techniques affect the attitudes of our students towards our discipline. Teaching strategies vary in their affect on student self-efficacy, but student-centered strategies, such as cooperative learning, have been shown to have a more positive correlation with the self-efficacy of physics students than traditional teacher-centered lecture (Shaw, 2005).
Chapter One: Introduction

With such a large discrepancy between conceptual and computational understanding it is clear that this area of research warrants further study. Though such an investigation requires much work on the part of the teacher, the need for a careful investigation should not be dismissed lightly. Peer Instruction has shown much promise in undergraduate physics lectures (Fagen, Crouch & Mazur, 2001). This study can help assess its effectiveness in the high school physics setting. Context rich problems have also proven successful at the undergraduate level (Jonsson, Gustafsson & Enghag, 2007; Park & Lee, 2004), where students prefer these “every-day” problems to traditional problems.

Research Questions

This research study investigated the relationships between teaching strategy, student self-efficacy, and the conceptual gain of high school physics students during a direct current unit. Specifically, this study sought answers to the following questions:

1. Do interactive-engagement teaching strategies yield higher conceptual gain than more traditional lecture strategies?
2. How does a student’s self-efficacy correlate with their performance on the conceptual based D.I.R.E.C.T. instrument, an assessment of conceptual understanding of direct current concepts?
3. Do interactive-engagement teaching strategies change a student’s self-efficacy?
4. Do self-efficacy and conceptual gain differ by gender?
5. How do students perceive interactive-engagement strategies, and how do students perceive the effectiveness of these strategies.

Significance

This study considers the role of the student in the learning process. Though research has shown a connection between student self-efficacy and student performance (Fencl & Sheel, 2005), most of the literature deals with undergraduate students. This study focuses exclusively on high school physics students. Perhaps more importantly, this study seeks not only to identify a connection between self-efficacy and performance, but to consider the implications for teaching. This study focuses on specific teaching strategies, providing quantitative and qualitative feedback about how these strategies affect student self-efficacy, and how students perceive the effectiveness of these teaching strategies. This research study may provide a basis for bringing context rich problems into the high school physics classroom.
Chapter One: Introduction

The researcher, and other physics teachers may continue to use teaching strategies that are not as effective as one might expect. The gap between student computational and conceptual understanding may continue to go largely unchanged. This study has the potential to support needed instructional change in this classroom and its findings may be applicable to other teaching situations. The study also provides students with a candid opportunity to share their feelings about how they learn.

Terms

*Interactive-engagement* – A type of learning that promotes conceptual understanding through hands-on activities that provide immediate feedback through discussion with peers or instructors (Hake, 72).

*Cooperative Learning* – A type of learning activity where students work in groups towards common learning goals (Johnson & Johnson, 1999). It is a form of interactive-engagement.

*Context Rich Problem* – A specific form of cooperative learning where groups work on realistic problems with a context. Problems are usually conceptual in nature and require a group effort (Heller & Heller, 1999).

*Peer Instruction* – A questioning strategy that uses conceptual questions, known as concept tests, as a form of informal assessment. Students are expected to discuss answers with their peers before responding (Mazur, 1997).

*Misconceptions* – Also referred to as alternative conceptions or naïve conceptions, misconceptions are incorrect ideas that occur when learners incorrectly attempt to reconcile new information with everyday experiences (Kikas, 2003).

*Self-Efficacy* – A person’s situation specific belief that he or she can succeed at a given task. (Fencl & Sheel, 2005).

Chapter Two: Literature Review

There exists a discrepancy between conceptual understanding in physics and the ability to score well on a traditional computation based physics exam. The source of this contradiction may be that misconceptions are difficult to change. Direct current misconceptions are particularly resistant to change, though student-centered, interactive-engagement teaching strategies have shown much success, particularly at the undergraduate level. Physics Education Research (PER) on the subject will be discussed and specific misconceptions in direct current electricity will be explained. Interactive-engagement concepts and activities, including Peer Instruction and context rich problems will be developed. The role of student self-efficacy will also be considered.

Misconceptions

When learners are presented with new information they attempt to integrate new ideas into their existing understandings. Learners attempt to reconcile new information with everyday experiences. When students interpret this new information incorrectly misconceptions are formed (Kikas, 2003). Kikas points out that scientific concepts differ greatly from every day concepts. While every day concepts are grounded in directly observable phenomena, scientific concepts are often abstract and understood in terms of complex relationships with other concepts. When trying to understand a scientific concept a student’s intuition does not always help, and sometimes interferes with, their ability to understand the scientific concept.

Students do not come into the classroom as blank slates. They come in with ideas of their own. Students come with preconceptions or naïve conceptions (Reiner, Slotta, Chi & Resnick, 2000) about the natural world that should not be dismissed. These ideas are a natural, and perhaps necessary, part of how students learn. Replacing these ideas is extremely challenging. Numerous studies have shown that traditional lecture-driven instruction is insufficient to change students’ conceptual understanding of physics (Hake, 1998; Hestenes, Wells, & Swackhamer, 1992). This holds true regardless of instructor or educational institution. As unsettling is it may be to a talented physics instructor, the quality of one’s lecture alone plays only a minor role in the conceptual change of students. To truly help students understand physics at the conceptual level, one must understand the “faulty” thought process of a student, rather than ignore it, or worse dismiss it.
Chapter Two: Literature Review

In 1987 the Harvard-Smithsonian Center for Astrophysics produced a documentary entitled, “A Private Universe” (Harvard, 1987). The opening sequence took place at a Harvard graduation ceremony. Graduating students, faculty, and alumni were asked two basic astronomy questions:

1) Why does the earth have seasons?

2) Why does the moon have phases?

Remarkably, only 2 out of 23 people interviewed, correctly answered both questions without revealing misconceptions. The most common incorrect answer for the seasons stated that it is warmer in the summer because the earth is closer to the sun. The earth is actually closest to the sun around January fourth. The longer days and more direct sunlight make it warmer. The most common incorrect answer for the phases of the moon question states that the earth partially blocks the light to the moon. The phases are actually a result of the relative positions of the earth, moon, and sun as the moon revolves around the Earth. In spite of many years of education, these intelligent adults carry with them misconceptions about seemingly simple scientific ideas from early high school. Misconceptions are deep-seated and difficult to change.

Part of the reason misconceptions are difficult to detect and change may have to do with the way terminology is used in science. Words used in class sometimes have different meanings outside of class. The documentary, “A Private Universe,” (Harvard) interviewed an articulate high school student, asking her to explain in detail her understanding of the seasons. The student explained that the winter is cooler because the sunlight is indirect. When pressed for an explanation of the term “direct”, the student stated that the light bounces off something before reaching the earth. This response was consistent with the student’s previous understanding of the term direct. This student’s initial answer of direct would have been correct on most tests, but the student would have continued to carry a major misconception (Coyle, 1994). Simply stating a word, such as direct, is not a good indication of conceptual understanding.

When students encounter new information that contradicts existing knowledge, they can replace existing ideas or reject them (Posner, Strike, Hewson & Gertzog, 1982). The deep-seated nature of misconceptions makes it difficult for students to make a conceptual change unless they first recognize their existing understanding, have their ideas challenged, and ultimately modify their understanding to accommodate new information. Students are often inconsistent in applying their conceptions. Students who
provide a correct explanation in one situation, may provide an incorrect explanation in another situation (Kikas, 2003). Explanations frequently depend on the context of the question. It is not a simple matter of replacing incorrect information with the correct information. Providing opportunities for students to identify and confront their own faulty reasoning is far more difficult than crafting a logical lecture. The teacher who embraces student misconceptions as part of the learning process is more likely to effect conceptual change.

**Misconceptions in Physics**

Misconceptions in physics are often based on incorrect assumptions. For example, many students believe that force implies motion (Kikas, 2003). This particular misconception, known as the impetus theory, was posited by Aristotle and was the dominant explanation of force and motion for over 1000 years. Many situations arise where the incorrect idea is reinforced by observation, rather than contradicted. The fact that misconceptions are logical and can often be used to explain phenomena makes them extremely difficult to overcome, especially when students and teachers are unaware of the misconceptions.

In physics, students often ascribe physical properties to ideas that are process related. In the impetus theory, students do not recognize force a process or a verb. Instead they visualize force as a substance that can be used up. Though this explanation provides a logical explanation for why a ball slows down as it moves through the air, it is incorrect. Such a personal theoretical foundation can be called a mental model (Borges & Gilbert, 1999). A mental model is an internal thought process that an individual uses to interpret and understand phenomena. It is a basis for making predictions. Such mental models may contain misconceptions and individuals often apply these models inconsistently (Reiner et al., 2000).

Explanations vary depending on the context and complexity of the problem.

Misconceptions in physics have been well documented. Some of the more common misconceptions include the impetus principle, the idea that an object runs out of force, and the dominance principle, the idea that bigger objects exert bigger forces. A well-established instrument, the Force Concept Inventory (FCI), was developed by a group at the University of Arizona (Hestenes et al., 1992). This multiple-choice instrument was designed to force students to choose between the correct Newtonian answer and incorrect common sense answers. The instrument was designed for use in a wide range of classrooms in high school and undergraduate settings. The questions probe student understanding of mechanics.
Chapter Two: Literature Review

principles through a variety of questions. In this way it is possible to gauge a student’s conceptual understanding of mechanics.

Intrigued by the earlier work of Hestenes et al., Erik Mazur began adding conceptual questions to exams in his introductory physics course at Harvard University (Fagen & Mazur, 1991). Mazur paired seemingly simple conceptual questions with seemingly more difficult calculation based questions. When he analyzed the data he found that there was virtually no correlation between student performance on numerical and conceptual questions. Some students who scored 100% on the numerical questions, scored 0% on the conceptual questions. Without a conceptual understanding of the underlying physics, students were approaching the numerical problems with a recipe like mentality. With a sufficiently large number of example problems and practice, students could score very well on traditional problems while failing similar conceptual problems. In one study, students who solved over 1000 traditional numerical problems over the course of a semester showed little improvement on conceptual questions (Kim & Pak, 2002).

A major hazard of traditional lecture is that it leaves students and teachers with a false sense of security (Mazur, 1997). Without a conceptual framework from which to interpret the natural world, physics degenerates into a series of cookie-cutter numerical calculations. In addition to stunting conceptual growth, traditional lecture can leave students with minimal interest in physics.

Common Misconceptions in Direct Current

Research on physics misconceptions has been more focused on mechanics (Reiner et al, 1999), but misconceptions about direct current circuits have also been well studied (Borges & Gilbert, 1999; Engelhardt & Beichner, 2004). Direct current misconceptions tend to be grounded in two incorrect assumptions that many students hold:

1) Current is consumed.
2) A battery is a source of constant current.

Often students apply mental models where current is an actual substance, rather than the flow of charge. Light bulbs and other resistive devices are seen as using up or consuming this current. Batteries are seen as the source of this substance, rather than as a source of energy. Voltage is confused with current and frequently viewed as a type of force. Students tend to think of voltage as a property of a current substance, rather than as an energy per charge (Reiner et al., 2000). This line of reasoning is usually applied
inconsistently, resulting in the incorrect interpretation of a variety of electrical phenomena. These misconceptions about current and voltage are further complicated by student misconceptions about electrical diagrams. Electrical diagrams or schematics are used to represent wires, batteries, resistors and other components of an electrical circuit. Many students view wires as pipes through which a type of electrical fluid flows. This makes it difficult for students to correctly identify complete and incomplete circuits. Students using this mental model find it difficult to distinguish between parallel and series circuits. These students also tend to view junctions within a circuit as purely local, with no effect on the rest of the circuit (Engelhardt & Beichner).

Engelhardt and Beichner developed a conceptual instrument, similar to the FCI, for assessing student misconceptions about direct current circuits. In determining the reliability of the instrument, over 1700 students from a wide variety of high schools, colleges, and universities were tested. Some of the most common misconceptions identified were:

1) Battery superposition; regardless of arrangement, two batteries will shine cause a light bulb to shine twice as brightly as one.

2) Battery as a constant current source; a battery supplies the same current to all circuits, regardless of arrangement.

3) Current consumed; current decreases as it moves through a circuit.

4) Local; current splits evenly at each junction, regardless of the resistance of each branch.

5) Sequential; only changes before a circuit element will affect that element.

6) Term confusion; resistance caused by current, voltage as property of current.

7) Topology; unable to distinguish physical arrangement from electrical arrangement (e.g. all resistors side by side are in parallel).

As with the student’s use of the word direct in “A Private Universe” (Harvard, 1987), many students correctly answer questions on traditional tests without developing a conceptual understanding. Simply stating an answer is insufficient evidence of understanding. This is especially true in physics where students’ mathematical abilities can mask their conceptual shortcomings. Many, if not most, introductory physics questions have been written in such a manner that than they can be answered by identifying a formula, plugging in values and computing the answer with a calculator. Many students obtain the correct
numerical answer through a faulty line of reasoning. These conceptual weaknesses persist from grade school through undergraduate, and even graduate education (Aarons, 1997).

**Changing Misconceptions Through Interactive-Engagement**

Identifying and helping students overcome misconceptions is a daunting task. As difficult as identifying misconceptions can be, it is even more challenging to change them. Traditional lecture-based classes, which are largely teacher-centered, do little to change the conceptual understanding of students (Hake, 1998). Simply hearing the correct information is not enough to change a student’s mind. The degree of conceptual change is strongly correlated with the amount of student engagement (Endorf, Koenig & Braun, 2006; Hake, 1998).

Endorf et al. studied the effects of student engagement in an introductory physics course at the University of Cincinnati. The study involved 272 of 390 students in the course. The students were offered extra credit for attending extra recitations on momentum and energy conservation in collisions, a topic not normally covered in the course. The students were distributed among four types of recitation: traditional lecture, students following a tutorial individually, students following a tutorial in cooperative groups, and students following a tutorial in cooperative groups with the teacher asking Socratic questions at checkpoints. All but the traditional lecture group used a tutorial developed by the Physics Education Group at the University of Washington. The lecture group used more traditional numerical problems. In the traditional lecture group the instructor presented the solutions and stated the major conceptual understandings the students were expected to reach. In the second group, the students worked individually then received the solutions to check their work. In the third group, the cooperative groups were given the solutions, similar to the second group. The fourth group was taught using the Socratic method. Instructors intervened at predetermined checkpoints to engage the students in a Socratic dialogue.

The pre-test revealed no significant differences between the four groups. The post-test showed no significant differences between the first three groups, but the Socratic group showed a difference from the other groups that was significant at the $p < 0.01$ level. The Socratic group scored twice as high as the other groups. This study suggests that cooperative groups where the teacher acts as a facilitator tend to show more conceptual change than individuals or groups without teacher interaction. Such groups also outperform groups where the teacher is primarily in charge of the instruction.
Chapter Two: Literature Review

Perhaps the single most cited study in the Physics Education Research community over the last 10 years is Richard Hake’s 6,000 student survey of conceptual understanding in mechanics (1998). The development of the Force Concept Inventory (Hestenes et al.) gave instructors a reliable method to evaluate student conceptual change in mechanics. Since 1992 a large number of high schools, colleges, and universities have used the FCI to evaluate their courses. Hake collected pre and post FCI data for 62 courses and 6,542 students. Hake categorized 14 courses as “traditional” and 48 courses as “interactive-engagement”. Interactive-engagement (IE) methods were defined as:

*those designed at least in part to promote conceptual understanding through interactive-engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors, all as judged by their literature description (Hake, 1998, p. 65).*

Traditional courses were those that did not use IE methods. A lecture-driven course would fit the traditional definition because students are given little time to interact. IE courses give students an opportunity to articulate their understandings of a concept. In “A Private Universe” (Harvard, 1987), as the young student defended her explanation of direct, she began to recognize the flaws in her reasoning. Prior to the interviewer asking for a more detailed explanation, the student was satisfied with a one-word answer, direct. Through this interactive dialogue the student was able to commit to her preconceptions, recognize some of the inconsistencies in her mental model, and ultimately undergo a conceptual change on camera.

To measure conceptual change, Hake calculated the average gain for each course from the pre-test to the post-test using the FCI. Gain, $g$, is defined as $\frac{Posttest - Pretest}{100 - Pretest}$ (Hake, 1998). Gain is a ratio of the actual improvement to the maximum possible improvement. For example, if a student scored 20 percent on the pre-test and 60 percent on the post-test, the gain would be calculated as $\frac{60 - 20}{100 - 20}$. Of the 80 points the student could have improved, the student improved 40. This would represent a gain of 0.5.

This method of calculating gain allows for a fair comparison of a wide range of courses with varied pre-test scores.

Hake found the average gain of the 14 traditional classes to be 0.23 +/- 0.04 while the average gain of the 48 interactive-engagement classes was nearly twice that at 0.48 +/- 0.14. The two groups differed by 1.8 standard deviations of the interactive-engagement group and 6 standard deviations of the traditional group. The results of this study offer resounding support for the effectiveness of interactive-
engagement teaching methods at all levels. This survey represents an unprecedented range of students and instructors from high schools, colleges and universities.

Interactive-engagement covers a wide range of teaching strategies that promote student engagement and dialogue. Cooperative learning (Johnson & Johnson, 1999) and Peer Instruction (Mazur, 1997) are two relatively broad IE strategies that have been used by the PER community to facilitate conceptual change. Within the context cooperative learning, certain strategies such as context rich problems (Heller & Heller, 1999) can be used to maximize learning. Peer Instruction can be broadened to include Peer Tutoring (Hairul & Joyce, 2005), where pairs of students alternate roles between tutor and student. Hairul & Joyce found that peer tutoring is most effective when students are give a script of questions to work through.

Though interactive-engagement covers a wide range of teaching strategies, all are student-centered. Student-centered teaching values, and requires, involvement of the student in his or her own education. Student-centered learning capitalizes on student differences, rather than ignoring them. This form of teaching differs radically from traditional teacher-centered instruction and requires that the teacher cede much of the responsibility for teaching to the students. In such a classroom the teacher becomes more of a facilitator than an orator. In reviewing literature on student-centered teaching Henson (2003) described five defining attributes of a student-centered classroom:

1. Education is experience based.
2. Individual student dispositions are considered in the planning of experiences.
3. The student’s perceptions shape the curriculum.
4. The student’s curiosity is fed and nurtured.
5. The learning is best when student emotions are involved.

Maintaining a student-centered classroom requires a large shift in perspective and much reflection on the part of the teacher. Running such a classroom is not easy, but the rewards are worth the effort.

Cooperative Learning

Cooperative learning is a student-centered form of learning that places the responsibility for learning on the student. Not all groupings of students constitute cooperative learning (Johnson & Johnson, 1999). A group of students who are assigned a task as a group, but compared to one another for a grade,
Chapter Two: Literature Review

make up a pseudo-learning group. Students in such a group will have no vested interested in the success of their group mates and may even mislead others intentionally. A pseudo-learning group does not promote constructive dialogue between students.

In a traditional learning group students are assigned work as a group, but graded as individuals. Individuals exchange information, but have little motivation to teach each other. This type of group permits a few individuals to do most of the work. Some students learn more than they would by working independently, but learning is not maximized.

A cooperative learning group is distinguished from a traditional learning group by shared goals among individuals. Individual performance is checked regularly. The quality of the group work is higher than the quality of work that would likely be produced by a single individual. A meta-analysis of 30 cooperative learning studies has shown that cooperative learning groups that function with individual and group goals perform better than groups that lack individual or group goals (Slavin, 1988). It should be cautioned that that such extrinsic motivation may erode students’ intrinsic motivation (Graves, 1991). In highly functioning cooperative groups students have an exceptional commitment to the success of one another (Johnson & Johnson, 1999).

Cooperative learning can be formal or informal. In formal cooperative learning teachers make pre-instructional decisions, explain the task, monitor student learning, and assess student learning (Johnson & Johnson, 1999). Though cooperative learning is student-centered, teachers exert great influence by controlling a number of factors including group size and composition, roles within the group, and materials available to the group. The teacher can specify the parameters of the task and explain how students are to interact. Required strategies and concepts may be taught. The teacher can systematically monitor the groups and intervene to help students work effectively together to accomplish the task. The teacher can assess the product of the group and can help students evaluate the functionality of the group.

Informal cooperative learning is similar to formal cooperative learning but the groups are more temporary and usually formed ad-hoc. Informal cooperative learning groups may last from a few minutes to a class period. These groups can provide students with an opportunity to interact with one another and rehearse explanations before sharing with the rest of the class.
Chapter Two: Literature Review

Context Rich Problems

Context rich problems are a specific form of cooperative learning that is more authentic than traditional problems. Context rich problems (CRPs) have several defining characteristics (Heller & Heller, 1998). CRPs are short stories written with the students as the primary characters. CRPs are deeply contextualized (Park & Lee, 2004), that is they involve every day experiences. This context serves to make the problem more concrete and to motivate the problem. CRPs are usually conceptual in nature and can not be solved by simple equation manipulation. CRPs may not contain all of the necessary information and usually contain information that is not required, or even helpful, to solve the problem. Usually CRPs do not contain figures or diagrams, which might prematurely restrict the thinking of a student. Students are left to draw from their own experiences to approach the problem. CRPs capitalize on student differences rather than ignore them. These problems are designed to foster a constructive dialogue between peers. This kind of problem is in stark contrast to the decontextualized computational problems typically found in a textbook. Context rich problems "hook" students and provide them with a sense of ownership.

When the context rich problem was developed by a group at the University of Minnesota (Heller, Keith & Anderson, 1992), a pilot study was conducted to investigate how these problems can be most effectively used. The study included two diverse populations from an introductory physics course of 120 students at a large research institution and 12 students in a modern physics course at a local community college. In both groups CRPs were used consistently throughout the semester. In the introductory physics course context rich problems were used during the 50 minute recitation period each week. CRPs were also used during the weekly two hour lab period. CRPs were used weekly in the modern physics course. Consistent with the recommendations of Slavin (1988) for group and individual goals, part of each student’s individual exam included a context rich problem that was worked out in a cooperative group. Students were also given a context rich problem to solve individually on the exam. This grading approach fosters positive interdependence (Johnson & Johnson, 1999).

The quality of student responses in a cooperative group setting versus an individual setting was evaluated by rating student solutions by Heller et al. (1992). When rated across six dimensions of expert problem solving, group solutions were significantly better than individual solutions to comparable problems. For the six exams in this study, the group median was 43% higher for problems solved in a group
than for comparable problems solved individually. The difference between group and individual performance on CRPs was most pronounced for conceptual understanding, useful physics description, and matching equations to the physics description. These skills are at the heart of expert problem solving.

Heller et al. (1992) described CRPs as a way to force students to solve problems more like experts. Novice students tend to proceed without a clear plan and quickly manipulate equations and calculate numerical answers. Experts develop a plan rooted in physical principles before beginning calculations. Along the way the reasonableness of answers is evaluated. Good CRPs reward critical thinking more than numerical calculation. Heller, Keith, and Anderson modeled an expert problem solving strategy, recommending the explicit teaching and consistent reinforcement of a five-step problem solving strategy:

1. Visualize the problem.
2. Describe the problem in physics terms.
3. Plan a solution.
4. Execute the plan.
5. Check and evaluate the solution.

In evaluating the performance of students on 1989 context rich problems Heller et al. made sure to explicitly instruct students on this problem solving method, and reinforce the strategy regularly. Student grades for CRPs were based on successful implementation of this problem solving method.

When grouping students, it is important to consider many factors including student performance, individual roles, and gender (Heller et al., 1992). For context rich problems, the ideal group size is two to six. Groups of mixed ability allow all students in the group to participate. Lower achieving students benefit from discussion with others, but higher achieving students benefit as well. For example, a high achieving student may not recognize a flaw in their assumptions until prompted by questions from others in the group. Gender is also important. Heller et al. found that single gender groups, and mixed gender groups of more than one female worked best. In groups consisting of two males and a female the male opinions often dominated the discussion, even when the female was a higher achieving student who voiced the more correct solution. Individual personalities also come into play, and Heller et al. recommend assigning roles within the group such as manager, skeptic, and recorder.
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Several studies have found that students prefer context rich problems to traditional computational problems (Jonsson, Gustafsson & Enghag, 2007; Park & Lee, 2004). Park found that Korean students preferred every day problems over any other type of problem. Problems involving living things and sports were second and third on the list. Problems involving labs and natural phenomena were much further down the list at fifth and sixth. Context rich problems can easily be written to include any of these topics. When students were presented with every day, or context rich problems, and decontextualized, textbook style problems, students preferred the context rich problems. Park is quick to point out that students were much more interested in problems where they had personal experience. For example, females might be less interested in certain sports problems than males. It is important to consider gender differences when selecting a problem.

Jonsson et al. (2007) examined the group dynamics that occur when students engage in cooperative learning. The study, which took place at a university in Sweden, found that students were all interested in the problem, had productive conversations, and solved the problem, but each group took a different path. Steps did not progress in the logical progression an expert would have followed, but all groups arrived at the correct answer. It was found that while some groups relied on the efforts of an individual, most groups progressed from an exploratory phase where each member contributed to the discussion, to a finishing phase where students articulated a model, to a calculation phase where the students arrived at a numerical answer. Lastly, each group discussed the reasonableness of the answer. Survey data indicated that these students felt context rich problems helped them better understand physics concepts and made problems more interesting. Data regarding whether students preferred context rich problems or decontextualized problems were inconclusive.

Peer Instruction

As a result of Erik Mazur's research into conceptual and numerical questions, Mazur developed an alternative to traditional lecture. This IE approach to lecture, known as Peer Instruction (1997), allows for more student interaction. At the heart of Peer Instruction is a questioning technique called a concept test. A concept test is a short, usually multiple-choice, conceptual question on a key idea from lecture.

When a concept test question is posed to the class, students are given about a minute to think about the question individually before responding. Students then record their answer. This answer can be in
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the form of a card that each student holds up, or it may be recorded electronically using a student response system. Students are then given one to two minutes to discuss their answers with their peers. Students are asked to “convince their neighbor”. This critical step, known as Peer Instruction, allows students to negotiate the merits of their answer and the answers of their peers. In this safe environment students can accept or reject the ideas of their peers and critique their own reasoning. This student-centered activity frees up the instructor to walk around the room and listen to students explaining their thought process.

After Peer Instruction, students respond again. If most students respond with the correct answer, the instructor may move on to the next lecture topic without further instruction. If many students still do not answer correctly, the instructor can provide a detailed explanation of the answer and adjust the lecture. Mazur was quick to point out that classes usually converge towards the correct answer and rarely move away from it. He posited that students who choose the correct answer for the right reasons are usually more confident in their answer and more difficult to make change their mind. Students who are unsure of their reasoning are more easily swayed by the arguments of their peers.

Peer Instruction requires far more time than traditional lecture to deliver information. To permit time for concept test questions and Peer Instruction, less material must be covered in class. In some instances content may be cut from a course, but this is usually not an option. Instead, students are expected to read before coming to class. Some ideas, especially basic facts, can be learned independently through reading. To reinforce this learning strategy, Peer Instruction employs reading quizzes in class. Since the inception of Peer Instruction in 1991, reading quizzes have been replaced with pre-class written responses (Crouch & Mazur, 2001).

Ten Years of Peer Instruction

Ten years of data show consistent gains of 0.5 to 0.8 on the FCI for both algebra and calculus based introductory physics courses at Harvard (Crouch & Mazur, 2001). Anything above 0.6 is considered a high gain (Hake, 1998). Over this period, five different instructors taught the course. Peer Instruction appears to be effective, regardless of instructor. The student response data before and after the Peer Instruction discussions was recorded over the fall 1997 semester. Crouch and Mazur found that students’ initial and final responses fell into four categories: correct twice (40%), incorrect to correct (32%), correct to incorrect (6%), and incorrect twice (22%). The data supports Mazur’s earlier position that relatively few
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students change from a correct answer to an incorrect one. From this study Crouch and Mazur conclude that the number of students who give a final correct answer is greatest when 35-70% of students initially have the correct answer.

Crouch and Mazur (2001) described the replacement of reading quizzes with pre-class free response questions as an important improvement to the Peer Instruction process. Students need an incentive to read, and guidelines for thinking about it before class. While the reading quizzes used in the early years of Peer Instruction provided motivation, they did not help students think about the reading. The pre-class questions consisted of two questions probing challenging ideas in the reading and one that asked, “What did you find difficult or confusing about the reading? If nothing was difficult or confusing, tell us what you found most interesting. Please be as specific as possible (p. 973).” Because students submitted responses via the internet before class, instructors could better prepare for the lecture.

A 2002 study examined the effectiveness of Peer Instruction in effecting conceptual change as measured by the Force Concept Inventory (Fagen, Crouch & Mazur, 2002). Data on the use of Peer Instruction was collected from a wide range of universities, courses, and instructors. Of more than 700 respondents, 108 provided quantitative pre and post-test data representing 30 courses. The average normalized gain for the courses was 0.39 +/- 0.09. Of 30 courses, 27 fell within the medium gain range, defined as 0.3 to 0.7 (Hake, 1998). In the Hake study, all of the traditional courses fell within the low gain range. Of the respondents using Peer Instruction, 90% reported that they would continue to use it in the future. More recently, many universities have begun using “clickers,” that allow students to submit their answers by pressing a button. Because each student is assigned a unique device, it is possible to collect data electronically from students in real time. Though this method allows instructors to evaluate concept test questions quickly, students using “clickers” appear to have the same conceptual gain as those using cards (Lasry, 2008).

A 2006 study at the Northern Arizona University looked at the effects of grading incentives on the discussions that occur during the student discussion phase of Peer Instruction (James). Two predominantly freshman undergraduate astronomy classes were examined. Of 264 students, 26 pairs of students carried tape recorders as they discussed the concept test questions throughout the semester. Student responses were later coded by two independent researchers for 10 categories of responses. Half of the pairs were in a high
stakes class where incorrect responses resulted in a lower course grade. Half of the pairs were in a low stakes classroom where students were graded for participation only. In the second group incorrect responses did not result in a lower grade.

The taped student discussions were coded for bias and imbalance in participation between members of the pair. Pairs in the high stakes classroom had twice the bias of the pairs in the low stakes classroom. The stronger student tended to dominate the conversations. Perhaps more striking than the conversation bias was the level of agreement. In the low stakes environment, members of the pair had different final responses 36.8% of the time while pairs in the high stakes classroom had different responses 7.6% of the time (James, 2006). This observed agreement may lead teachers to falsely assume that most students are “getting it,” when in reality the ideas of a few are being allowed to dominate. If students feel they will be penalized for expressing their true beliefs, conceptual gain will not be optimized.

**Physics Self-Efficacy**

Teaching strategies can do much to improve the learning of a student, but the student’s own perception of their abilities may be equally important. Self-Efficacy (Bandura, 1977) is the belief a student holds that he or she can succeed at a task in a particular context. A review of self-efficacy literature shows a correlation between a number of factors related to academic success (Bong, 1977). Students with high self-efficacy tend to be more willing to undertake a challenging task, exert greater effort on a task, and persist when confronted with obstacles. These skills are invaluable when solving physics problems. Additionally, high self-efficacy students show less anxiety, employ more effective learning strategies, and self-regulate well.

Though the foundations of the self-efficacy concept described by Bandura (1977) are rooted in psychology, the concept translates to the field of education. While Bandura presents self-efficacy as a predictor of behavioral change such as overcoming one’s fears, there also appears to be a strong correlation between self-efficacy and success in the classroom. Hackett et al. (as cited in Fencl & Sheel, 2005) found that self-efficacy was a stronger predictor of college GPA than interest. This predictive value of self-efficacy may shed some light on the gender differences that exist in science enrollment. Though science enrollment numbers are similar for boys and girls in elementary and middle schools, males increasingly
outnumber females as students progress through high school, college, and graduate studies (Murphy & Whitlegg, 2006).

Interestingly, girls tend to exhibit higher science self-efficacy than boys in middle school (Britner & Pajares, 2006). This difference may be related to stronger verbal skills in girls than boys at this age. This difference appears to shift by college. To examine the self-efficacy of students at the undergraduate level, a physics self-efficacy instrument was developed and field-tested at Southern Illinois University. The study included 356 Conceptual Physics students, 84 College Physics students, and 77 University Physics students. The first two courses contained approximately equal numbers of men and women, while the University Physics course was three three-fourths male. The introductory College Physics course showed a statistically significant difference between male and female self-efficacy, while the more challenging College, and University Physics courses show no significant gender difference. The gender difference in self-efficacy may be leading female students to drop more challenging science courses before males students with similar performance. This troubling trend highlights the importance of understanding how self-efficacy operates in the science classroom.

In Bandura’s model, self-efficacy can be changed through four mechanisms: performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal. Performance accomplishments, also known as mastery experiences, provide a tangible experience. The success or failure of a student at a particular task greatly influences future behavior. In general, mastery experiences have shown the strongest correlation with self-efficacy change (Britner & Pajares). Vicarious experiences allow students to learn by observing others. Based on the feedback gained from watching others, students can reflect on the likelihood that they would succeed at a similar task. Social persuasion such as the praise or criticism of peers can bolster or weaken self-efficacy. Physiological states such as stress or excitement play a role as well. Too much or too little can undermine self-efficacy.

In considering the four change mechanisms for self-efficacy, it is important to remember that the four mechanisms do not work independently, but rather inextricably. A student engaged in a mastery experience will likely be observing the successes and failures of peers. The feedback and judgments of others will influence the mastery experiences attempted by the student, as well as the physical and emotional state of the student. A closer inspection of Bandura’s definition of self-efficacy reveals an
important distinction from response-outcome expectancies, or locus of control. Locus of control is the
degree to which an individual believes his or her actions will result in a particular action. Self-efficacy is a
measure of an individual's confidence that they can actually carry out those actions. Teasing out this
difference from experimental data is often difficult as the two concepts are closely related. Operationally
we attempt to infer self-efficacy from observable outcomes that are the result of a subject’s actions, as it is
more difficult to actually measure one’s beliefs. Similarly it a challenge to separate the effects of the four
self-efficacy change mechanisms. Self-efficacy requires the cognitive processing of change events.

Fencl and Sheel (2005) examined the impact of teaching strategies on self-efficacy in an
undergraduate algebra based physics course for non-science majors. A 33 question Self-efficacy in Science
Courses survey was administered to 218 students in multiple class sections using different teaching
strategies. Strategies that show the strongest correlation with self-efficacy included cooperative learning,
conceptual learning problems, electronic applications and inquiry based labs. Each of these strategies
allowed students to interact socially with one another and qualitatively with the material. These more
student-centered methods allow for mastery experiences, vicarious experiences, and social persuasion.

The paradox of successful students who struggle with conceptual questions is a quiet but ever
present problem in physics teaching. The misconceptions that students carry are a challenge that must be
dealt with systematically. Teachers must not take such difficulties as a personal affront on their lecture
skills, but rather as a natural part of the learning process. Instead of trying to provide better explanations,
teachers should shift the focus of the class to helping students recognize, challenge, and revise their
thinking. Watching pupils struggle can be uncomfortable for a teacher, but without a structured, but
personal struggle, few students will gain conceptual understanding and intuition.

A second related struggle in the science classroom is the role of self-efficacy. Self-efficacy is a
fragile, but critical part of student success. Students with high self-efficacy tend to outperform students
with low self-efficacy, creating a self-fulfilling prophecy. The self-efficacy gap between boys and girls
appears to grow as students get older. This decreasing self-efficacy of girls in high school may be partly to
blame for the decreasing enrollment of females in upper level physics. Because self-efficacy is not a
constant, it should be considered and nurtured in the classroom. Students should be provided with
opportunities for personal mastery, vicarious experiences, and social persuasion.
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Interactive-engagement strategies such as cooperative learning, context rich problems, and Peer Instruction have demonstrated success effecting conceptual change and positively influencing self-efficacy. Much of the research in these areas has focused on undergraduate education. A study of several interactive-engagement strategies in a secondary classroom may provide additional insight into the effectiveness of these strategies and how they can best be implemented in a high school setting. The results of such a study would offer a case study of interactive-engagement in a secondary physics classroom and the findings may be generalizable to a broader audience.
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Research Questions

This research study investigated the relationships between teaching strategy, student self-efficacy, and the conceptual gain of high school physics students during a direct current unit. Specifically, this study sought answers to the following questions:

1. Do interactive-engagement teaching strategies yield higher conceptual gain than more traditional lecture strategies?
2. How does a student’s self-efficacy correlate with their performance on the conceptual based D.I.R.E.C.T. instrument, an assessment of conceptual understanding of direct current concepts?
3. Do interactive-engagement teaching strategies change a student’s self-efficacy?
4. Do self-efficacy and conceptual gain differ by gender?
5. How do students perceive interactive-engagement strategies, and how do students perceive the effectiveness of these strategies.

Participants

All participants were enrolled in an introductory college preparatory physics course at a suburban high school outside of Rochester, NY. All participants were current students in the researcher’s Regents Physics course. Most students had previously met the science requirements for graduation and elected to enroll in the course. All enrolled students completed algebra and geometry before taking the course. The majority of students completed a course in trigonometry before taking the course, though several were taking trigonometry concurrently. Most students were from upper middle class families with strong parental support for education. Six students had an individualized education plan, with extended time on tests as the primary accommodation.

Regents Physics is an introductory algebra based physics course, typically taken in 11th or 12th grade. The course covers topics in mechanics, waves, electricity and magnetism, and modern physics. The researcher taught all four sections of the Regents Physics course that were offered in the 2007-2008 school year at the high school. Approval from the building principal was obtained several months prior to the study. Several weeks prior to the direct current unit, the purpose, methods, and potential benefits of the study were explained to each of the four sections. It was explained that participation or non-participation in the study would neither help nor harm a student’s grade. Of the 66 students enrolled in the course, 54...
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students elected to participate in the study. Student and parental consent forms were obtained from all participants prior to beginning the study. The study included 35 boys and 19 girls with 19 eleventh grade students and 35 twelfth grade students.

Measuring Conceptual Understanding of Direct Current Concepts

Though several well-established instruments exist for assessing conceptual understanding of mechanics concepts (Hestenes, 1992), relatively few general instruments have been designed to study misconceptions dealing with direct current circuits (Engelhardt & Beichner, 2004). Tests have been developed, but most of them are too closely tied to a particular course or research study to be as generally applicable as the Force Concept Inventory. Engelhardt and Beichner sought to fill this gap by developing the Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT). DIRECT was developed to test for a variety of direct current student conceptions.

Content validity was a primary concern in the development of the instrument. Before writing the instrument, Engelhardt and Beichner consulted a wide range of high school and university textbooks, lab manuals, and instructors to establish objectives. The objectives were reviewed by an independent panel of experts before any questions were written. The panel raised some concerns about the lack of meters in the questions. Most courses include the use and interpretation of ammeters and voltmeters to measure current and voltage. The authors intentionally excluded meters from the objectives because they viewed meter reading as a skill rather than a concept. Many students falsely believe that meters significantly change a circuit. The authors wanted to assess student understanding of electricity concepts without allowing misconceptions related to the measurement to get in the way. The 11 objectives assessed by the DIRECT instrument fall into the following categories:

1. Physical aspects of DC electric circuits.
2. Energy
3. Current
4. Potential Difference

Items were initially written as open-ended questions. Multiple questions were written for each objective. Questions were written in three modes, verbal to schematic, realistic to schematic, and schematic to realistic. Some items were taken from textbooks, while others were suggested by the panel. Most
questions were written by Engelhardt and Beichner. The questions were specifically written without a single instructional approach in mind to make the instrument as widely applicable as possible. Multiple choices were then added to each question. Like the Force Concept Inventory (Hestenes, 1998), each question has a correct choice, and several common sense incorrect choices. A copy of the DIRECT instrument can be obtained by contacting Dr. Robert Beichner at North Carolina State University. In the current study, the DIRECT instrument was used as a pre-test and post-test for conceptual understanding of direct current concepts.

**Measuring Physics Self-Efficacy**

The Self-Efficacy Survey (Shaw, 2004) was designed to measure a student’s belief in his or her physics ability. Self-efficacy is believed to be context dependent. The instrument (Appendix, p. 2) consists of a short eight-question survey on a Likert scale from 1 to 5. Five questions were written in positive language, and three questions were written in negative language. The minimum possible score was an 8, while the maximum possible score was a 40. Each question was designed to be gender and culturally neutral. In a study of approximately 500 undergraduate physics students, a weak correlation was noted between self-efficacy scores and end of term rank. This correlation was strongest for female non-engineering majors. The current study administered this self-efficacy survey at the beginning and end of the unit as a general measure of physics self-efficacy. As an additional measure of self-efficacy, students were also asked to make a prediction about their performance on the DIRECT instrument before completing it (Appendix, p. 1).

**Experimental Design**

The 54 participants were categorized into two groups based on which section they were enrolled. The two morning sections of Regents Physics were designated the lecture group. The two afternoon sections of the course were designated the interactive-engagement (IE) group. The grouping of the four sections into two groups was made arbitrarily so that the groups were approximately equal in size and gender composition. The lecture group contained 16 boys and 10 girls. The IE group contained 19 boys and 9 girls. Each section was taught by the researcher and met five days a week for 40 minutes at the same time each week. Each section met for an additional lab period one day a week. During this lab period, the lecture group and the IE group received identical instructions and performed identical labs. Because lecture and IE
students were slightly mixed during lab periods, each lab session was deliberately taught identically without the use of interactive-engagement methods.

Each of the four sections, ranging from 12 to 22 students, was taught by the researcher in the same classroom. This physics classroom was arranged into six immovable student stations of approximately two feet by ten feet of laminated tabletop. Each student station, which doubles as a lab station, sat up to four students and included one to two desktop computers. The classroom contained dry-erase boards at the front of the room and a video projector connected to a desktop computer operated by the researcher. A class set of two foot by three foot student dry-erase boards were in the classroom and utilized by the IE students, but not by the lecture students.

This study took place over three and a half weeks during the direct current electricity unit from late April to mid-May of 2008. Prior to instruction, all participating students completed the Physics Self-Efficacy Survey. Participants were then given five minutes to read over the 29 question DIRECT instrument. Students were instructed to think carefully about how many questions they expected to get correct. After making a DIRECT prediction, students were given 30 minutes to complete the DIRECT Instrument. Non-participating students completed an ungraded enrichment activity about lightning safety.

Throughout the unit, the lecture group and the IE group were instructed in the same content through two different methods. The lecture group was instructed exclusively through traditional lecture. Each lesson consisted of the researcher lecturing. At times students were given some time to work alone. Though students sometimes turned to their neighbor for help, they were never encouraged to do so and were never formally placed into groups. Questions asked to the class were generally asked orally, and a single student was called upon to answer each question. Usually the first student to raise their hand was called on.

The interactive-engagement (IE) group was instructed primarily through interactive-engagement techniques, including Peer Instruction, cooperative learning, and context rich problems. At the beginning of the unit, students were grouped into nine groups of three students. A group of three is large enough to permit the sharing of ideas, but small enough to foster positive interdependence and individual accountability (Johnson & Johnson, 1999). The cooperative learning groups were maintained throughout the unit. Consistent with the recommendations of Heller et al. (1992), students were placed into mixed
ability groups as determined by first semester average. Each group of three was single gender or two girls and a boy. This was intended to avoid a situation observed by Heller et al. where two boys tend to dominate the conversation over a single female group member. The primary function of the group was to work cooperatively on solving seven context rich problems (Appendix, pp. 3-9) over the course of the unit. Each student was labeled an “electron”, “proton”, or “neutron”. These labels were used as a convenience for assigning individual roles within the group. The IE group received some lecture, but much less than the lecture group. Instead of whole period forty-minute lectures, the IE group received much shorter fifteen-minute or less lectures with concept test questions (Appendix, pp. 10-13) interspersed throughout. Over the course of the unit, fifteen concept test questions were asked of the class using an interactive-engagement technique known as Peer Instruction (Mazur, 1997).

At the conclusion of the unit, all students took the same unit test. The following day all participants completed the Physics Self-Efficacy Survey, made a DIRECT score prediction, and took the DIRECT instrument again according to the same procedure used before instruction four weeks earlier. Additionally the IE group completed the Concept Test Survey (CTS) (Appendix, pp. 15-16) and the Context Rich Problem Survey (CRS) (Appendix, pp. 17-18). Unlike the other instruments the Concept Test Survey and the Context Rich Survey were taken anonymously to encourage students to provide honest feedback. Both the CTS and CRS were written by the researcher to collect qualitative and quantitative feedback about these two teaching strategies. Non-participating students worked on a non-graded enrichment activity about electrical safety.

The CTS asked participants to agree or disagree with nine statements about concept test questions according to a Likert scale ranging from one to five. Similar to the Physics Self-Efficacy Survey some questions were worded positively, while others were worded negatively. The maximum possible score on this survey was a 45, while the lowest possible score was a 9. CTS scores were calculated by dividing the cumulative score by nine. The CRS asked participants to rank each of the seven context rich problems according to four dimensions: difficulty, interest, educational value, and degree of recommendation for use with future classes. Both surveys asked free response questions to collect qualitative data about student perceptions of each strategy.
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Peer Instruction

In the IE group, concept based questions known as concept tests were used two to four times per week. Over the course of the unit, 15 concept test questions were used. These concept test questions usually revolved around one or two conceptually challenging ideas and were used as part of a broader instructional approach known as Peer Instruction (Mazur, 1997). Peer Instruction as developed by Erik Mazur requires that lecture include several concept test questions. Students are asked the question, given some time to think individually and polled, using student response cards or a computerized student response system. Students are then given some time to discuss the choices with peers. This discussion of the concept test questions with peers, is at the heart of the Peer Instruction method. Students are then polled a second time.

In the IE group, each concept test question was projected onto a screen at the front of the room as a power point slide. The question was read out loud to the students. Students were then given one to two minutes to think about the question quietly to themselves. The class was then polled using student response cards (Appendix, p. 14). When asked for an answer all students in the class held up the letter of their choice at the same time. The cards were color coded so that the researcher could quickly assess the answer distribution in the classroom. Student responses were not recorded by the researcher, but the relative distribution of answers was acknowledged by the researcher and shared with the class. When most of the class answered correctly, the results were summarized by the teacher, skipping the Peer Instruction phase. When differences of opinion were noticed, students were encouraged to talk to students with different answers. Students were encouraged to, “convince your neighbor.” A student response system, known as “clickers”, would have recorded student answers, but would have been costly.

Of the 15 concept test questions used in this study, 9 were obtained from Project Galileo (ILT-BQ Consortium, 2006). Project Galileo was started by Erik Mazur and serves a resource for teachers utilizing Peer Instruction. The remaining six concept test questions were written by the researcher. The student response cards, created by the researcher from Microsoft Office clip art included cards for A, B, C, D, “?”, “Trick Question”, “Agree”, and “Disagree”. The latter four cards were used during informal questions. These informal questions did not follow the Peer Instruction method and sometimes did not have a correct answer. For example students were asked to respond to statements such as, “If I were given a quiz on this topic right now, I think I would get a 100.” Students were also asked questions where the correct response
was "Trick Question" or "?". This happened when students were not given enough information or when certain assumptions had to be made. The student response cards were distributed at the beginning and collected at the end of each period.

**Context Rich Problems**

In the IE group context rich problems (CRPs) (Heller, 1999) were used as a form of cooperative learning. Six CRPs, called “physics tales,” were written by the researcher. A seventh CRP was adapted from the Physics Education Group at the University of Minnesota (Circuit Problems, 2007). Each problem was written according to specific guidelines (Heller). The CRPs were written in the form of a contextualized (Park & Lee, 2004) short story where the student is the primary character. The questions were usually written implicitly and did not layout a specific set of steps for the student to follow as many textbook problems do. Instead students must collaborate to identify assumptions, frame out the problem, devise a plan, and reach a common solution. Most of these problems did not give students complete figures or diagrams as these might restrict student thinking. The CRPs were more difficult than problems given on a typical test and were largely conceptual in nature. They were intended to stress the application of principles more than complicated calculation. This design encourages students to discuss the problem with their group mates and explore the problems in terms of their own experiences.

At the beginning of the unit, the purpose of “physics tales” was explained to students and the groups were assigned. To help focus students and promote positive interdependence and individual accountability, each student was assigned to one of three roles: moderator/skeptic, researcher, or idea manager. The moderator periodically restated the question, and recapped the group’s previous and current strategies. The moderator was also responsible for keeping track of time. The idea manager also served as the skeptic who was responsible critiquing the group’s ideas. The role of the researcher was to carefully comb the problem for information, and locate information from other sources such as class notes, the textbook, and the internet. The idea manager was responsible for writing information on a white board or white boards (Bush & Kelly, 2004) as the group worked out a solution, and recording the group’s solution on paper. This single solution required communication between group members. Though each student had a role, all were responsible for helping the group reach a solution. Group roles were rotated throughout the unit.
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Group solutions were collected and examined by the researcher, but not graded. Students had not previously received group grades, and were not used to receiving group grades in this course. Also, grading participants would lead to different grades for participants and non-participants because the IE group would receive grades that were not received by the lecture group. When students consented to participating in this study they did so under the assumption that participation or non-participation in the study would not affect their grade. Group solutions were collected by the researcher, and comments were made. Some comments were made to the individual groups, while others were made to the entire class. Sometimes groups were asked to share their solutions on a two foot by three foot whiteboard. The intended major understandings for each problem were restated to the class. In the lecture group, less context rich, more traditional textbook problems were used as substitutes for the CRPs. The problems were worked out by the teacher on the board and the major understandings were stated.

Data Analysis

To answer the first research question, “Do interactive-engagement teaching strategies yield higher conceptual gain than more traditional lecture strategies?” the mean and standard deviation of the DIRECT score was calculated for the lecture and IE groups before and after instruction. The gain (Hake, 1998), 
\[
\frac{Posttest - Pretest}{100 - Pretest}
\]
, was calculated and expressed as a percentage. The change from pre-instruction DIRECT score to post-instruction DIRECT score and the gain were used as a measure of conceptual gain. A two-tailed t-test was performed to evaluate the significance of the difference between the lecture and IE groups.

To answer the second research question, “How does a student’s self-efficacy correlate with their performance on the conceptual based D.I.R.E.C.T. instrument, an assessment of conceptual understanding of direct current concepts?” two measures of self-efficacy were used. Overall physics self-efficacy was measured using the pre-instruction Physics Self-Efficacy Survey for all participants. Pre-instruction DIRECT predictions were used as a second measure of self-efficacy. Self-Efficacy scores were grouped into high, medium, and low scores based on percentile. Actual pre-instruction DIRECT scores were also grouped into high, medium, and low based on percentile. The average DIRECT score and standard deviation were calculated for the high, low, and medium self-efficacy scoring students. To evaluate the statistical significance of any differences between high, medium, and low scoring students, a t-test was
performed between high and low self-efficacy students. Because, high, medium, and low scores set up categorical data for DIRECT performance and self-efficacy, a chi-squared test was performed as an additional measure of statistical significance.

To answer the third research question, "Do interactive-engagement teaching strategies change a student's self-efficacy?" gain in self-efficacy and DIRECT predictions scores were calculated. Because the lecture and IE groups received two different methods of instruction, this calculation was carried out separately for each group. The significance of any differences in pre-instruction and post-instruction was evaluated using a two-tailed t-test. The difference in conceptual gain between the lecture and IE groups was also evaluated using a t-test.

To answer the fourth research question, "Do self-efficacy and conceptual gain differ by gender?" self-efficacy scores before and after instruction were compared for boys and girls. Again, both the Physics Self-Efficacy Survey and the DIRECT prediction were used as a measure of self-efficacy. Comparisons were made between all boys and all girls, IE girls and IE boys, lecture boys and lecture girls, IE girls and lecture girls, and IE boys and lecture boys. The average and standard deviation was calculated for each group for both measures of self-efficacy. All comparisons were made before and after instruction. Pre-instruction differences, post-instruction differences, and self-efficacy gain were calculated. The statistical significance of each difference between groups was calculated using a two-tailed t-test.

To answer the fifth research question, "How do students perceive interactive-engagement strategies, and how do students perceive the effectiveness of these strategies?" Anonymous qualitative and quantitative data from the Concept Test Survey and the Context Rich Problem Survey was compiled. For each of the first nine concept test survey questions, the average degree of positive response for each question was calculated. Responses of five to positively worded questions indicated a strongly positive response. For questions worded negatively, a one indicated a strongly positive response and was averaged as a five. Similarly, a response of five to a negatively worded question was averaged as a one. On the Context Rich Problem Survey, the average ranking for all seven CRPs was calculated for each of the four dimensions: difficulty, interest, educational value, and degree of recommendation for use with future classes. The average rating for each of the seven context rich problems was plotted for each of the six combinations of the four dimensions. A linear regression was performed on each of the 6 plots to measure
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the degree of correlation between dimensions. Student responses to the open ended questions on each survey were compiled.

Limitations

It should be noted that this study has some limitations which may limit its generalizability. This study reflects a single unit over a relatively short three and a half week period. It includes a single pre-test and post-test with only one measure of conceptual gain. The study of interactive-engagement is limited to the use of Peer Instruction and context rich problems. There are many other teaching strategies that would fall under the category of interactive-engagement, but it would not be practical to use many of these strategies in a single unit. It was decided by the researcher that it would be better to use Peer Instruction and context rich problems consistently, than to use many strategies inconsistently. Adding other strategies would also make it harder to conclude that any specific strategies were correlated with conceptual or self-efficacy change. Many of the concept test questions and six out of seven of the context rich problems used in this study were written by the author with no external evaluation or test for validity. Drawing conclusions about either teaching strategy based solely on this study would be premature.

The cross section of students represented in this study may be somewhat different than at other institutions where the conclusions of this study may or may not be applicable. For example, physics at this school is an elective. Students with low self-efficacy might not be enrolling in the course at the same rate as students with high self-efficacy, potentially skewing the results. A school where physics is required might yield different results in a similar study.

Because the two groups were composed of only four sections, it is possible that the dynamics of a given section may have affected the self-efficacy or conceptual gain. If this were the case, it may not be clear whether observations were better correlated with the instructional methods used by the researcher or the section of students themselves. With only four sections, it is not possible to know for sure. An alternative might have been to have both interactive-engagement and traditional groups of students in the same classroom. Such a design would likely have required much more time. With only one instructor in the room this was not practical for a single instructional unit, and would likely have compromised the distinction between the two teaching methods for a given group.
Chapter Three: Methods

Finally, it should be noted that the lecture and IE groups were both taught by the same teacher, the researcher. Though students were enrolled in different sections, students from each section talked with one another. Students may have questioned why the teaching techniques of one section were different from one another. Given this communication there is some danger of the Hawthorne and John Henry Effects. Some students may have put more effort into this unit than others because they knew that this was the unit being studied. The two sections that were traditional lecture may have realized they were the control group, and some students may have put in more effort to compensate. Increasing the number of physics teachers and students in the study may have helped with many of these challenges, but it was not possible.
Chapter Four: Results

An Overview of the Data

This study investigated the relationships between interactive-engagement versus traditional lecture instruction, student self-efficacy, and gender. This investigation was organized around five specific research questions, with each question rooted in specific quantitative data. The DIRECT instrument served as an objective measure of conceptual understanding of direct electricity concepts. The Physics Self-Efficacy Survey was used as a measure of overall physics self-efficacy. DIRECT score predictions made by participants served as a second measure of self-efficacy. The Concept Test Survey (CTS) measured student perceptions of Peer Instruction using a Likert scale. The Context Rich Problem Survey (CRS) asked participants to rank each context rich problem according to difficulty, interest, educational value, and degree of recommendation for use with future classes. The CTS and CRS also collected qualitative feedback from participants about student perceptions of these two teaching strategies.

All instruments except for the CTS and CRS were given both pre-instruction, and post-instruction. In making comparisons between groups, whether IE versus lecture, or boys versus girls, two measures of comparison were used. Post-test scores were one measure and gain was another. Though post-test scores are one measure of difference, they can be heavily influenced by pre-instructional differences in two populations. Gain is one way of accounting for pre-instructional differences. Loosely defined as the ratio of actual improvement to maximum possible improvement, gain is calculated according to the formula,

\[
\text{Gain} = \frac{\text{Posttest} - \text{Pretest}}{\text{Pretest}} \times 100
\]

Conceptual gain was calculated using the DIRECT instrument, overall physics self-efficacy gain was calculated using the Physics Self-Efficacy instrument, and DIRECT predictions were used as another measure of self-efficacy. To evaluate the statistical significance of any differences between populations, a two-tailed t-test was performed. For t-tests and chi-squared tests, results were considered statistically significant for \( p \) values smaller than \( p < .05 \). Results with \( p \) values smaller than \( p < .1 \) were considered noteworthy, but not statistically significant.

Interactive-Engagement vs. Traditional Lecture

The DIRECT scores for the interactive-engagement and traditional lecture groups were compared, Table 4.1. Before instruction the IE group scored slightly higher than the lecture group, but this difference was not statistically significant. After instruction the IE group scored significantly higher, 9.2%. Both
groups showed positive conceptual gain. The difference in conceptual gain between groups was noteworthy ($p < .091$), with the IE group demonstrating 9.7 percentage points more gain than the lecture group.

Table 4.1

**DIRECT Scores for Interactive-Engagement vs. Lecture**

<table>
<thead>
<tr>
<th></th>
<th>IE (N=28)</th>
<th>Lecture (N=26)</th>
<th>aSignificance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT (pre-instruction)</td>
<td>28.6% +/- 13.7%</td>
<td>24.8% +/- 12.2%</td>
<td>$p &lt; .270$</td>
</tr>
<tr>
<td>DIRECT (post-instruction)</td>
<td>40.8% +/- 12.7%</td>
<td>31.6% +/- 11.2%</td>
<td>$p &lt; .006$</td>
</tr>
<tr>
<td>bGain</td>
<td>16.9% +/- 16.5%</td>
<td>7.2% +/- 23.9%</td>
<td>$p &lt; .091$</td>
</tr>
</tbody>
</table>

aTwo-tailed t-test b(Post-Pre)/(100-Pre)

**Conceptual Understanding vs. Self-Efficacy**

Student pre-instruction DIRECT predictions were grouped into high, medium, and low based on the top, middle, and bottom third of predictions. The average pre-instruction DIRECT score was reported for the high and low groups (Table 4.2). High predicting students outperformed low predicting students by two percentage points, but this difference was not statistically significant. Student pre-instruction physics self-efficacy scores were also grouped into high, medium, and low based on the top, middle, and bottom third of physics self-efficacy scores before instruction. The average pre-instruction DIRECT score was reported for the high and low self-efficacy groups (Table 4.3). High self-efficacy students scored 0.4 percentage points higher than low self-efficacy students, but this difference was not statistically significant.

Table 4.2

**Pre-Instruction DIRECT Scores for High DIRECT Predictions vs. Low DIRECT Predictions**

<table>
<thead>
<tr>
<th></th>
<th>High Prediction</th>
<th>Low Prediction</th>
<th>aSignificance</th>
<th>bSignificance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT Score</td>
<td>29.1% +/- 13.9%</td>
<td>27.1% +/- 10.8%</td>
<td>$p &lt; .612$</td>
<td>$p &lt; .360$</td>
</tr>
</tbody>
</table>

aTwo-tailed t-test bchi-squared test
Chapter Four: Results

Table 4.3

*Pre-Instruction DIRECT Scores for High Self-Efficacy vs. Low Self-Efficacy*

<table>
<thead>
<tr>
<th></th>
<th>High Self-Efficacy</th>
<th>Low Self-Efficacy</th>
<th>aSignificance</th>
<th>bSignificance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT Score</td>
<td>23.1% +/- 13.8%</td>
<td>22.7% +/- 10.7%</td>
<td>p &lt; .455</td>
<td>p &lt; .120</td>
</tr>
</tbody>
</table>

*a two-tailed t-test  b chi-squared test

Self-Efficacy Change vs. Instructional Method

Average pre-instruction and post-instruction DIRECT predictions were reported for the interactive-engagement and the lecture groups (Table 4.4). Both groups showed an increase of slightly more than 20 percentage points in the prediction. There was no significant difference between the groups before or after instruction. Similarly, there was no significant difference in the prediction gain of each group.

Table 4.4

*DIRECT Predictions for Interactive-Engagement vs. Lecture*

<table>
<thead>
<tr>
<th></th>
<th>IE (N=28)</th>
<th>Lecture (N=26)</th>
<th>aSignificance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction (pre-instruction)</td>
<td>53.2% +/- 20.9%</td>
<td>49.7% +/- 24.3%</td>
<td>p &lt; .560</td>
</tr>
<tr>
<td>Prediction (post-instruction)</td>
<td>75.1% +/- 14.9%</td>
<td>70.1% +/- 17.8%</td>
<td>p &lt; .259</td>
</tr>
<tr>
<td>bGain</td>
<td>15.4% +/- 143%</td>
<td>38.0% +/- 32.2%</td>
<td>p &lt; .866</td>
</tr>
</tbody>
</table>

*a two-tailed t-test  b (Post-Pre)/(100-Pre)

Average pre-instruction and post-instruction physics self-efficacy scores were reported for the interactive-engagement and lecture groups (Table 4.5). There was no significant difference between groups before or after instruction and neither group showed a significant change from pre-instruction to post-instruction. The physics self-efficacy gain was slightly positive for the lecture group and slightly negative for the IE group, but in both cases the uncertainty was almost as large as or greater than the measured gain. There was no statistically significant difference in self-efficacy gain between the two groups.
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Table 4.5

Physics Self-Efficacy Scores for Interactive-Engagement vs. Lecture

<table>
<thead>
<tr>
<th></th>
<th>IE (N=28)</th>
<th>Lecture (N=26)</th>
<th>(^a)Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>^b^Pre-instruction SE</td>
<td>32.62 +/- 5.58</td>
<td>32.16 +/- 3.24</td>
<td>(p &lt; .703)</td>
</tr>
<tr>
<td>^b^Post-instruction SE</td>
<td>33.27 +/- 5.38</td>
<td>32.82 +/- 3.34</td>
<td>(p &lt; .709)</td>
</tr>
<tr>
<td>^c^Gain</td>
<td>-2.4% +/- 78.6%</td>
<td>10.5% +/- 26.2%</td>
<td>(p &lt; .429)</td>
</tr>
</tbody>
</table>

\(^a\)two-tailed t-test \(^b\)Scale of 5 to 40 \(^c\)(Post-Pre)/(40-Pre)

DIRECT Predictions vs. Gender

Direct predictions before and after instruction for all girls and boys were recorded and the resulting gain was calculated (Table 4.6.). Before instruction, the boys’ predictions were significantly higher than the girls’ predictions. On average the predictions of the boys exceeded the predictions of the girls by 19.1 percentage points. This difference was significant at the \(p < .001\) level. After instruction boy predictions exceeded girl predictions by a much smaller margin of 6.5 percentage points, but this difference was not statistically significant. The gain for all girls was 8.7 percentage points higher than the gain for all boys, but this difference was not statistically significant.

Table 4.6

DIRECT Predictions for Boys vs. Girls

<table>
<thead>
<tr>
<th></th>
<th>Boys (N=35)</th>
<th>Girls (N=19)</th>
<th>(^a)Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction (pre-instruction)</td>
<td>58.2% +/- 23.1%</td>
<td>39.1% +/- 15.9%</td>
<td>(p &lt; .001)</td>
</tr>
<tr>
<td>Prediction (post-instruction)</td>
<td>75.1% +/- 16.5%</td>
<td>68.6% +/- 15.8%</td>
<td>(p &lt; .153)</td>
</tr>
<tr>
<td>^b^Gain</td>
<td>35.5% +/- 36.5%</td>
<td>44.8% +/- 24.2%</td>
<td>(p &lt; .322)</td>
</tr>
</tbody>
</table>

\(^a\)two-tailed t-test \(^b\)(Post-Pre)/(100-Pre)

DIRECT predictions before and after instruction were tabulated for boys in the IE group, and boys in the lecture group (Table 4.7.). Consistent with Table 4.6, pre-instruction predictions from both groups of boys were about 19% higher than the pre-instruction predictions from girls in the same instructional group. Before instruction there was no statistically significant difference in DIRECT predictions between IE and
Chapter Four: Results

lecture boys. After instruction, predictions for boys in both groups went up about thirty percentage points. After instruction, the IE boys' predictions were 8.7% higher than the lecture boys' predictions, but this difference was not significant. The two groups had similar gains of about 35%.

Table 4.7

<table>
<thead>
<tr>
<th></th>
<th>IE Boys (N=19)</th>
<th>Lecture Boys (N=16)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction (pre)</td>
<td>59.3% +/- 21.5%</td>
<td>57.0% +/- 25.2%</td>
<td>p &lt; .758</td>
</tr>
<tr>
<td>Prediction (post)</td>
<td>79.0% +/- 12.7%</td>
<td>70.3% +/- 19.6%</td>
<td>p &lt; .116</td>
</tr>
<tr>
<td>Gain</td>
<td>33.6% +/- 36.2%</td>
<td>37.1% +/- 37.8%</td>
<td>p &lt; .207</td>
</tr>
</tbody>
</table>

*two-tailed t-test *(Post-Pre)/(100-Pre)*

DIRECT predictions before and after instruction were tabulated for girls in the IE group, and girls in the lecture group (Table 4.8). Consistent with Table 4.6, pre-instruction predictions from both groups of girls were about 19% lower than the pre-instruction predictions from boys in the same instructional group. Both IE girls, and lecture girls made pre-instruction predictions of about 39% with no significant difference between the two groups. After instruction the predictions of girls in the IE group were 2.7% less than predictions of girls in the lecture group, but this difference was not statistically significant.

Table 4.8

<table>
<thead>
<tr>
<th></th>
<th>IE Girls (N=9)</th>
<th>Lecture Girls (N=10)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediction (pre)</td>
<td>40.2% +/- 12.6%</td>
<td>38.2% +/- 18.5%</td>
<td>p &lt; .782</td>
</tr>
<tr>
<td>Prediction (post)</td>
<td>67.2% +/- 16.6%</td>
<td>69.9% +/- 15.7%</td>
<td>p &lt; .710</td>
</tr>
<tr>
<td>Gain</td>
<td>44.7% +/- 25.1%</td>
<td>45.0% +/- 24.7%</td>
<td>p &lt; .982</td>
</tr>
</tbody>
</table>

*two-tailed t-test *(Post-Pre)/(100-Pre)*
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Self-Efficacy vs. Gender

Physics self-efficacy scores before and after instruction for all girls and all boys were recorded and the resulting gain was calculated (Table 4.9.). Before instruction, the boys' physics self-efficacy scores were notably \( p < .064 \) higher than the girls' self-efficacy scores. The average self-efficacy score for boys exceeded the average self-efficacy score for girls by 2.24 on a scale of 5 to 40. After instruction the average self-efficacy score for boys exceeded the average self-efficacy score for girls by 1.06, but this difference was not statistically significant. There was no significant difference in self-efficacy gain between boys and girls.

Table 4.9

<table>
<thead>
<tr>
<th></th>
<th>Boys (N=34)</th>
<th>Girls (N=19)</th>
<th>(^a)Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-instruction SE</td>
<td>33.19 +/- 4.13</td>
<td>30.95 +/- 4.64</td>
<td>( p &lt; .064 )</td>
</tr>
<tr>
<td>Post-instruction SE</td>
<td>33.44 +/- 4.31</td>
<td>32.38 +/- 4.84</td>
<td>( p &lt; .394 )</td>
</tr>
<tr>
<td>Gain</td>
<td>7.6% +/- 42.3%</td>
<td>-2.0% +/- 80.1%</td>
<td>( p &lt; .572 )</td>
</tr>
</tbody>
</table>

\(^a\)two-tailed t-test \(^b\)Scale of 5 to 40 \(^c\)(Post-Pre)/(40-Pre)

Physics self-efficacy scores before and after instruction were tabulated for boys in the IE group, and boys in the lecture group (Table 4.10.). Before instruction, boys in the IE group scored 0.75 higher than boys in the lecture group on a scale from 5 to 40. This difference was not significant. After instruction this difference rose slightly to 2.15, but was still not significant. Though the IE boys showed a gain 18.7% higher than the lecture boys, this difference was not significant.
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Table 4.10

*Boys’ Physics Self-Efficacy Scores for Interactive-Engagement vs. Lecture*

<table>
<thead>
<tr>
<th></th>
<th>IE Boys (N=19)</th>
<th>Lecture Boys (N=16)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-instruction SE</strong></td>
<td>33.59 +/- 5.03</td>
<td>32.84 +/- 3.25</td>
<td><em>p &lt; .596</em></td>
</tr>
<tr>
<td><strong>Post-instruction SE</strong></td>
<td>34.40 +/- 4.67</td>
<td>32.25 +/- 3.59</td>
<td><em>p &lt; .139</em></td>
</tr>
<tr>
<td><strong>Gain</strong></td>
<td>16.7% +/- 56.4%</td>
<td>-2.0% +/- 14.9%</td>
<td><em>p &lt; .207</em></td>
</tr>
</tbody>
</table>

*a two-tailed t-test  bScale of 5 to 40  c(Post-Pre)/(40-Pre)*

Physics self-efficacy scores before and after instruction were tabulated for girls in the IE group, and girls in the lecture group (Table 4.11.). Before instruction, girls in the lecture group scored 0.3 higher than girls in the IE group on a scale from 5 to 40. This difference was not significant. After instruction this difference rose slightly to 2.64, but was still not significant. The IE girls showed a negative gain, while the lecture girls showed a positive gain. This difference was statistically notable (*p < .057*), but the IE girls’ gain had a large uncertainty of over 100%.

Table 4.11

*Girls’ Physics Self-Efficacy Scores for Interactive-Engagement vs. Lecture*

<table>
<thead>
<tr>
<th></th>
<th>IE Girls (N=9)</th>
<th>Lecture Girls (N=10)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-instruction SE</strong></td>
<td>30.78 +/- 6.42</td>
<td>31.08 +/- 3.03</td>
<td><em>p &lt; .886</em></td>
</tr>
<tr>
<td><strong>Post-instruction SE</strong></td>
<td>31.00 +/- 6.22</td>
<td>33.64 +/- 2.91</td>
<td><em>p &lt; .221</em></td>
</tr>
<tr>
<td><strong>Gain</strong></td>
<td>-30.8% +/- 103%</td>
<td>38.0% +/- 28.1%</td>
<td><em>p &lt; .057</em></td>
</tr>
</tbody>
</table>

*a two-tailed t-test  bScale of 5 to 40  c(Post-Pre)/(40-Pre)*

**Student Perceptions of Peer Instruction**

After instruction, interactive-engagement students were given the 13 item Concept Test Survey. The first nine questions asked students to agree or disagree with statements about concept tests. The average student response for each question was recorded (Table 4.12). A rating of 1 indicated strong disagreement, while a 5 indicated strong agreement, and a 3 indicated a neutral response. The average
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Rating for all nine items was greater than 3, indicating an average positive response to all questions. Item seven received the least positive response with an average rating of 3.27. Item eight received the most positive response with an average rating of 4.27.

Table 4.12

Interactive-Engagement Student Ratings of Concept Test Questions

<table>
<thead>
<tr>
<th>CT #</th>
<th>Question</th>
<th>*Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concept Test questions help me understand physics better.</td>
<td>3.87 +/- 1.28</td>
</tr>
<tr>
<td>2</td>
<td>I frequently learn from my peers when discussing a Concept Test question.</td>
<td>3.47 +/- 1.20</td>
</tr>
<tr>
<td>3</td>
<td>Discussing a Concept Test question with my peers increases the likelihood that I will get the correct answer.</td>
<td>3.87 +/- 1.20</td>
</tr>
<tr>
<td>4</td>
<td>I learn more when I discuss a Concept Test question with my peers than when I do not discuss the question.</td>
<td>3.67 +/- 1.35</td>
</tr>
<tr>
<td>5</td>
<td>I am more likely to share my thoughts with the class after discussing a Concept Test question with a peer.</td>
<td>3.53 +/- 1.25</td>
</tr>
<tr>
<td>6</td>
<td>Explaining the answer to a Concept Test question helped improved my understanding.</td>
<td>4.17 +/- 1.02</td>
</tr>
<tr>
<td>7</td>
<td>I would rather hear the answer to a Concept Test question immediately from the teacher, than spend time discussing the question with my peers.</td>
<td>3.27 +/- 1.57</td>
</tr>
<tr>
<td>8</td>
<td>I think Concept Test questions are an inefficient use of class.</td>
<td>4.27 +/- 0.98</td>
</tr>
<tr>
<td>9</td>
<td>I would learn more with less concept tests and more time devoted to lecture.</td>
<td>3.90 +/- 1.32</td>
</tr>
</tbody>
</table>

Average rating for all questions 3.77 +/- 1.24

*Scale of 1 to 5 where 1 indicates strong disagreement, 5 indicates strong disagreement, and 3 is neutral.

For negatively worded questions scores were reported positively by subtracting the actual rating from 6.

Items 10 to 13 were free response questions that asked students to share what they liked and disliked about the Peer Instruction process using concept tests, and what could be done to improve the process. Each response was reported anonymously (Appendix, pp. 20-22) with the corresponding average concept test rating for that student. Responses to each item were reported from most positive to least positive concept test rating.

Students described a wide range of benefits of the Peer Instruction process ranging from general content based statements such as, “helps represent what will be on tests,” to specific advantages of Peer
Instruction over traditional lecture, "...provided insight that may not have been given by the teacher."

Many students described the benefits of collaboration, specifically the sharing of ideas, the diversity of perspectives, and the chance to discuss or practice their ideas in small groups. Several students referred to an increase in their active participation, including one who stated, "It forced me to do more on my own and learn it better," and another who wrote, "They make me think more. I am an active learner and it helps to do the problem, not just watch." Another student commented that concept test questions were, "like a game... My favorite part of class."

Students also offered several criticisms of the Peer Instruction method. Most criticisms dealt with time. Some students felt that the concept test questions took up too much class time, while others commented that they did not always have enough time to think about the questions. One student noted that concept test questions, "...sometimes, they would get drawn out with all the discussing." Another student commented that, "It is sometimes not necessary." A few students made statements indicating that they preferred traditional lecture, such as, "I'd rather have you skip the discussion with peers. I want to hear the answer straight from you." Other students commented that discussions with peers sometimes led to confusion. Only 2 of 28 interactive-engagement students made statements indicating strong disapproval for the Peer Instruction Method. Both of these students had an average concept test rating of 1.78 out of 5. Only one other student had a concept test rating of less than 3.

The interactive-engagement students offered several suggestions for improving the use of Peer Instruction and concept tests. Some recommended allowing more time for thinking while others suggested speeding up questions. It was suggested that some questions be based on something interactive such as a picture or video. One student suggested that the teacher pair up students before asking the question. Students also suggested the use of "life lines," such as removing a choice during the Peer Instruction phase. It was also recommended that these questions be used more frequently throughout course.

**Student Perceptions of Context Rich Problems**

To evaluate student perceptions of the specific context rich problems used in this study, interactive-engagement students completed the Context Rich Problem Survey. The first section of the survey asked students to rank each of the seven context rich problems used during the unit according to four categories: interest, difficulty, educational value, and recommendation for future use. The average
ranking for each problem was recorded for each of the four categories (Table 4.13). Problem four, “Disarming the Megacircuit,” was the most interesting, while problem three, “The Electrician’s Mystery Medallion,” was the least interesting. Students found problem seven, “Who Needs the Electric Company?” to be the most difficulty, and problem three, “The Electrician’s Mystery Medallion,” to be the least difficult. By a large 1.00 ranking margin, students found problem four, “Disarming the Megacircuit”, to be the most educational. By a large 1.09 ranking margin students found problem one, “Penning a Powerful Cartoon,” the least educational problem. Problem two, “Where is the Short?” was the most recommended, while problem seven, “Who Needs the Electric Company?” was the least recommended problem.

Table 4.13

<table>
<thead>
<tr>
<th>Context Rich Problem</th>
<th>Interest</th>
<th>Difficulty</th>
<th>Educational Value</th>
<th>Recommended For Future Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Penning a Powerful Cartoon</td>
<td>5.16 +/- 1.73</td>
<td>4.31/2.30</td>
<td>5.48 +/- 1.86</td>
<td>4.54 +/- 2.19</td>
</tr>
<tr>
<td>2 Ohm My Where is the Short</td>
<td>3.67 +/- 1.81</td>
<td>4.00/1.69</td>
<td>3.53 +/- 1.94</td>
<td>2.89 +/- 1.64</td>
</tr>
<tr>
<td>3 The Electrician’s Mystery Medallion</td>
<td>5.63 +/- 1.56</td>
<td>4.83/1.95</td>
<td>3.90 +/- 2.01</td>
<td>3.90 +/- 2.06</td>
</tr>
<tr>
<td>4 Disarming the Megacircuit</td>
<td>2.38 +/- 1.54</td>
<td>3.55/1.96</td>
<td>2.53 +/- 1.72</td>
<td>3.39 +/- 1.99</td>
</tr>
<tr>
<td>5 Circuito</td>
<td>4.71 +/- 1.76</td>
<td>4.25/1.80</td>
<td>4.04 +/- 1.86</td>
<td>4.48 +/- 1.78</td>
</tr>
<tr>
<td>6 Remote Surgery by a Fine Wire</td>
<td>3.26 +/- 1.37</td>
<td>4.20/1.86</td>
<td>4.13 +/- 1.46</td>
<td>4.00 +/- 1.65</td>
</tr>
<tr>
<td>7 Who Needs the Electric Company?</td>
<td>3.34 +/- 1.91</td>
<td>3.04/1.79</td>
<td>4.39 +/- 1.83</td>
<td>4.66 +/- 1.90</td>
</tr>
</tbody>
</table>

*All ratings represent the average of 28 student rankings from 1 (most) to 7 (least) for a given problem in a given category.*

To examine the relationship between how student rankings in one category related to student rankings in another category, a scatter plot was created for each of the six possible combinations of two categories. A linear regression was performed on each scatter plot. The slope, y-intercept, and correlation coefficient of each regression was reported (Table 4.15). None of the six combinations of categories yielded a strong negative correlation. Student interest showed a strong positive correlation with the perceived difficulty of the context rich problem by the student (Figure 4.14). A strong positive correlation was also noted between the degree to which students recommended a context rich problem and the perceived difficulty of problem. A more moderate positive correlation was noted between the perceived educational value and difficulty of a problem.
Chapter Four: Results

Figure 4.14

*Scatter Plot and Linear Regression of the Average Student Interest and Perceived Difficulty Ratings of Context Rich Problems.*

**Interest vs Difficulty**

![Scatter Plot and Linear Regression](image)

\[ y = 0.3778x + 2.5061 \]
\[ R^2 = 0.5809 \]

Table 4.15

*Correlations Between Context Rich Problem Ranking Categories*

<table>
<thead>
<tr>
<th>Comparison</th>
<th>(^aM)</th>
<th>(^bB)</th>
<th>(^cR^2)</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Interest vs. Difficulty</td>
<td>0.38</td>
<td>2.51</td>
<td>0.58</td>
<td>Strong Positive</td>
</tr>
<tr>
<td>2 Recommended vs. Educational</td>
<td>0.52</td>
<td>1.88</td>
<td>0.51</td>
<td>Strong Positive</td>
</tr>
<tr>
<td>3 Educational vs. Difficult</td>
<td>0.46</td>
<td>2.16</td>
<td>0.36</td>
<td>Moderate Positive</td>
</tr>
<tr>
<td>4 Recommended vs. Difficulty</td>
<td>0.21</td>
<td>3.14</td>
<td>0.14</td>
<td>Weak Positive</td>
</tr>
<tr>
<td>5 Interest vs. Educational</td>
<td>0.15</td>
<td>2.44</td>
<td>0.05</td>
<td>Uncertain</td>
</tr>
<tr>
<td>6 Interest vs. Recommended</td>
<td>-0.06</td>
<td>-0.06</td>
<td>0.00</td>
<td>Uncertain</td>
</tr>
</tbody>
</table>

\(^a\)Slope of the Linear Regression  \(^b\)Intercept of the Linear Regression  \(^c\)Correlation Coefficient of the Linear Regression

The second section of the Context Rich Problem Survey asked open-ended questions about context rich problems and the functioning of groups as they tried to solve these problems. All student responses were recorded (Appendix, pp. 22-25). Several commented that these problems were more
realistic, making statements such as, "They helped demonstrate physics principles in the real world." Another student commented that it was, "interesting to apply concepts to life like problems." Others commented on how these problems were different than typical problems, "...That was fun. I liked the nonconventional way of solving problems." Numerous students reported liking that context rich problems were, "Harder than normal questions." Several students had positive things to say about working in groups, "Working in a group was fun." Another student wrote, "I liked being the skeptic or the manager."

The criticisms reported by the students generally involved problem difficulty, time, or unequal participation of group members. Several students reported that problems were, "too hard," or "....very hard and a lot to take in." Several students called the problems confusing. Students also reported that the problems, "...took longer than they should have." A few students described their group as unproductive with "social loafing". These students described situations where one or two of the people in the group did most of the work.

Question four of the survey asked, "Do you think you learned more by working in a group on these problems, than you would have working alone?" Out of 28 interactive-engagement students surveyed, 22 students responded yes, while 3 students answered no, and 3 students gave an ambiguous response or did not answer. When asked to elaborate on how working as a group differed from working alone, students provided several insights. The majority of responses highlighted the sharing of ideas with statements such as, "It was good because you could ask for help or pool brains." There were many similar comments such as, "Two heads are better than one." Several students mentioned that the quality of their answer improved, "...discussed answers, and got better answers." One student did comment that working in a group was, "...at times beneficial, and at others overkill."
Chapter Five: Discussion

In this study the relationships between interactive-engagement teaching strategies, conceptual gain, and self-efficacy were examined. During a three week electricity unit in a suburban college preparatory level Regents Physics classroom, two sections of high school students were taught using Peer Instruction and context rich problems, while the other two sections were taught using traditional lecture methods. Surveys for conceptual understanding and physics self-efficacy were given to both groups before and after instruction.

After instruction the interactive-engagement students scored significantly higher on the DIRECT instrument used to measure conceptual understanding of direct current concepts. The IE group scored 40.8%, while the lecture group scored 31.6%. Both of these averages are consistent with the 36% average DIRECT score of high school students measured during field testing of the DIRECT instrument during its development (Engelhardt & Beichner, 2004). The 16.5% gain for the IE group versus the 7.2% gain was not statistically significant at $p < .09$, but was notable.

The gains shown by both groups were relatively modest compared to typical gains on the Force Concept Inventory, FCI. On the FCI low gain is generally considered below 30%, medium gain is considered 30% to 60% and high gain is considered greater than 60% (Hake, 1998). Despite the comparatively small gains shown in the DIRECT instrument, it may not be fair to categorize these gains as low. Unlike the FCI, which covers a wide range of mechanics concepts, the DIRECT instrument covers a narrow range of less intuitive electrical concepts. The time between pre-test and post-test was about four weeks in the current study, whereas the post-test FCI is normally given at the end of semester or school year. During that time there has been far more time for practice and the application of concepts than was permitted in the current study. Given these considerations, the difference in gain likely represents a real difference.

In evaluating the effectiveness of interactive-engagement versus traditional methods, it is important to note that this study represented only two strategies. These two strategies were believed by the researcher to be representative of interactive teaching methods, but many others could have been employed as well. It is hoped that this exploratory study provides a least some preliminary justification for the use of more interactive-engagement strategies in the physics classroom. Though the scope of this study was
Chapter Five: Discussion

restricted to a single unit in a physics classroom, these strategies may be effective in other units, other disciplines, and even other age groups.

Student self-efficacy was evaluated through two measures, a general Physics Self-Efficacy Survey, and student predictions of performance on the DIRECT instrument. On both of these measures, students with higher self-efficacy performed only slightly better than low self-efficacy students and the difference was not statistically significant. It may be worth questioning whether a student's performance prediction is a strong indicator of actual self-efficacy. Because self-efficacy represents a student's belief, it can be difficult to measure. There may be other factors influencing student predictions to such a degree that student predictions may not accurately reflect student beliefs about ability. At seven questions in length, the Physics Self-Efficacy Survey (Shaw, 2004) also may not be a true indicator of a student's overall physics self-efficacy. This study did not support a relationship between self-efficacy and performance, but it did not contradict such a relationship either. According to Bandura (1977), self-efficacy can change through performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal. These elements are present in both concept tests and context rich problems. The uncertainty in self-efficacy measurement should not be interpreted as the ineffectiveness of interactive-engagement strategies. More refined measures of self-efficacy combined with longitudinal studies could provide more insight into the impact of teaching strategy on self-efficacy.

Self-efficacy was compared before and after instruction using the DIRECT predictions and the Physics Self-Efficacy Survey. Student predictions for both IE and lecture groups were about 50% before instruction and 75% after. There was no significant difference between IE and Lecture, but there was a large positive increase in predictions after instruction for both groups. This increase for both groups is not surprising given that students came into the course with relatively little prior knowledge about electrical concepts. As mentioned earlier, DIRECT predictions may not be a strong indicator of self-efficacy and the change in predictions may be more strongly influenced by presence of instruction than by the type of instruction. There was no significant difference in physics self-efficacy scores between pre-instruction and post-instruction or between IE and lecture students. Self-efficacy is difficult to measure, and overall physics self-efficacy is a deep-seated belief that is difficult to change over the course of a single unit of
Chapter Five: Discussion

instruction. This study did not support a relationship between the type of instruction and self-efficacy change, but it did not contradict such a relationship either.

The actual student performance on the DIRECT instrument was approximately the same for boys and girls with no statistically significant difference between the groups. Both boys and girls exhibited approximately the same gain and showed no statistically significant difference after instruction. At the school represented in the current study, approximately 50% of all students take physics before graduating, which is above the national average of 27% (Hehn & Neuschatz, 2006). Though two-thirds of the students in this study were boys, girls and boys performed equally well. This discrepancy highlights a common gender imbalance in physics (Murphy & Whitelegg, 2006). Though girls and boys performed equally well, more boys were enrolled in the course than girls. This discrepancy appears to increase in higher education where only 20% of physics degrees are awarded to women (Hehn & Neuschatz). It is hoped that interactive-engagement teaching strategies that allow students to interact with one another, such as those in this study, may help interest and retain girls in the field. A broader longitudinal study encompassing a wide range of schools may help show the effects of teaching strategies on course selection and career choice.

The pre-instruction DIRECT predictions revealed a remarkable difference between boys and girls. The boys’ average DIRECT prediction before instruction was 58.2%, while the girls’ average prediction was 39.1%. Statistically significant at the $p < .001$ level, this difference highlights a stark difference between boys and girls. After instruction the gap was essentially erased. Though DIRECT predictions did not correlate with actual performance in this study, these predictions may play a role in the low enrollment of women in advanced physics. Perhaps girls do not anticipate being successful in advanced physics so they do not enroll in courses? Again, it is hoped that the use of interactive-engagement teaching strategies help keep women in the field by giving them opportunities to be successful, learn from others, and develop genuine interest in the subject.

The Physics Self-Efficacy Survey did not reveal significant differences between boys and girls before or after instruction, though boys did rate themselves 2.24 out of 40 points higher before instruction. This difference was noteworthy with a statistical significance of $p < .064$ (Table 4.9.). Girls’ self-efficacy went from 30.95 to 32.38, while the boys’ self-efficacy score went up a smaller margin from 33.19 to 33.44. Curiously, the average of the self-efficacy gain of each girl was −2.0%, even though the average
Chapter Five: Discussion

self-efficacy score went up. The self-efficacy gain calculated from the average girl pre-instruction self-efficacy score and the average girl post-instruction self-efficacy score was 24.8%. This large discrepancy is an artifact of the way gain is calculated. When the pre-test is close to 100%, even a small change from pre to post represents a large percentage change. When that change is negative, it is actually possible to get a negative gain with a magnitude greater than 100%. A closer inspection of the self-efficacy data (Appendix, p. 19) reveals that several students had very high pre-instruction scores, and consequently large negative gains. Student 28, an interactive-engagement girl, had a gain of $-300\%$. The relatively high pre-instruction self-efficacy scores, combined with the difficulty in assessing self-efficacy mentioned earlier, make it difficult to draw meaningful conclusions about self-efficacy differences.

The Concept Test Survey revealed strong support for the use of Peer Instruction. On a scale of 1 (strongly dislike) to 5 (strongly like), students gave concept tests an average rating of 3.77 with only 10% of students giving a rating of less than 3. Though a few students cited the time required for the Peer Instruction process as a drawback, the response from students was overwhelmingly positive. Many students cited the diversity of perspectives, sharing of ideas, and active participation as benefits of the method. Students offered several recommendations including using audio-visuals in the question and focusing on concepts over calculations. Given the positive feedback of students it is clear that Peer Instruction has benefits that extend beyond its ability to increase conceptual understanding. Concept test questions and the discussions they create allow students to make meaningful connections. Students quickly recognize that they are not alone in their misconceptions.

Student support for context rich problems was generally positive, but not as strong as for Peer Instruction. Many students reported that these problems were more realistic and applicable to real life than typical problems. Students also reported that solving these problems in groups was easier than trying to solve them alone because students could share ideas and stay focused. Students commented that the context rich problems were time consuming and sometimes confusing. At the same time, there was a strong positive correlation between the perceived difficulty of a problem and student interest. There was also a moderate positive correlation between perceived educational value and difficulty.

Context rich problem four, “Disarming the Megacircuit,” was rated the most interesting problem and the most educational, yet it was rated the second most difficult. This problem followed the guidelines
Chapter Five: Discussion

set by the University of Minnesota (2007). The problem puts students directly in the story as protagonists with a strong motivation to complete the problem, in this case to avoid blowing up on the way to a job interview. The problem has enough detail to permit a solution, but is sufficiently open ended so as to force meaningful discussions of recently learned physics principles to solve the problem. Though students dislike problems that are unnecessarily difficult or poorly written, they seem to prefer problems that are realistic, but within reach when students work collectively. Writing such a problem requires careful planning.

Over the course of three and a half weeks, seven context rich problems were completed. Each problem required between 10 and 40 minutes to complete. This time was valuable and did help students learn, but given student response it may be better to emphasize quality over quantity. Students clearly preferred some problems over others. While the Physics Research Group at the University of Minnesota has researched guidelines for effective problems and has posted example problems on their website, much could be gained from field testing more problems in a variety of classrooms. In this way teachers could utilize problems that most effectively hook students and help them work through difficult concepts. High quality problems are a challenge to write. Such a collaborative undertaking could help teachers hone their context rich problem writing skills and open the door for more teachers to use this interactive-engagement strategy.

While Peer Instruction and context rich problems appear to have helped increase conceptual understanding of direct current electricity concepts in the current study, more research needs to be done before generalizing these findings to other concepts or groups of students. This study was limited to two particular educational strategies that fall under the relatively broad umbrella of interactive-engagement. More research needs to be done to determine the degree to which these findings apply to other student-centered teaching strategies in a wider range of teaching situations. Though it is presumed other strategies that promote positive student interaction could produce similar results more research must be done to substantiate this claim. Such research could also help resolve which interactive-engagement strategies work best for particular situations.

The implementation of the Peer Instruction process requires explicit student instruction on how to use the process. Teaching students how to use this strategy was not difficult, and was an essential prerequisite to using this strategy effectively. Initially some students found it difficult not to talk to their
peers during the initial posting of the concept test questions, but overall students took to this technique relatively quickly, likening it to a game show. Little external motivation was required to get students to participate in the Peer Instruction Process. The quickly identified misconceptions, clarifying discussions, and quick feedback were sufficiently engaging.

Context rich problems were much more of a challenge to implement. In this study students were put into formal cooperative learning groups for the first time all year. Because of the relatively short nature of the study, students were only given cursory instruction on how to function as a group. For context rich problems to work better, more time should have bee spent discussing group processing (Johnson & Johnson, 1999). Students did not have time to practice the interpersonal skills necessary to work cooperatively. The roles assigned within each group helped build some individual accountability, but more individual and group accountability could have been built in if the problems had been graded and students quizzed on the problems individually. To ensure that participants were not graded differently than non-participants, context rich problems were not graded in this study. There would be value in studying the differences between graded and ungraded context rich problems in terms of conceptual change and student perception.

This study provided strong support for the use of interactive-engagement teaching strategies for promoting conceptual understanding of direct electricity concepts in the high school physics classroom. Students using Peer Instruction and context rich problems showed significantly greater conceptual change than students receiving traditional lecture. This difference appears to be true regardless of gender. Overall self-efficacy showed little difference before and after instruction or between genders, with one notable exception. Before instruction student performance predictions were significantly higher for boys than girls despite similar performances. The use of these strategies was also supported by student opinions, which indicated a preference for challenging realistic problems.
References


*Educational Leadership, 48*(7), 77-79.


*Education, 124*(1), 5-16.


You are about to take a 29 question multiple-choice questionnaire on direct current electricity concepts. Each question is followed by five possible choices. Each question has one and only one correct answer. Your results will be recorded as part of my research study, but your results will never be reported with your name. Please take few minutes to look over the questionnaire, but do not write anything down. You will be instructed to start shortly.

Please make a prediction of how many questions you expect to answer correctly. Please enter a number between 0 and 29 in the space below. Your prediction will not affect your score, and your performance on the questionnaire will not affect your grade in this course.

Name: __________________

Predicted Score out of 29: __________
Physics Survey

Think about how these questions have been used during class. For each statement please circle the number that best represents your level of agreement. There are no right or wrong answers, and your answers will not affect your grade. I will be using this anonymous survey in my research study to evaluate the use of Concept Test questions in our class and to decide how to use these questions in the future.

1) I am very comfortable when I use a computer.
   (Disagree) 1 2 3 4 5 (Agree)

2) I can solve for the variable $r$ in the expression $F = Gm_1m_2/r^2$
   (Disagree) 1 2 3 4 5 (Agree)

3) I have a good intuition about how nature behaves.
   (Disagree) 1 2 3 4 5 (Agree)

4) I consider myself very good at math.
   (Disagree) 1 2 3 4 5 (Agree)

5) I have a very difficult time solving word problems.
   (Disagree) 1 2 3 4 5 (Agree)

6) I consider myself very poor at science.
   (Disagree) 1 2 3 4 5 (Agree)

7) I have a hard time using math in science classes.
   (Disagree) 1 2 3 4 5 (Agree)

8) I can figure out how long it will take to travel from Detroit to Chicago at 55 miles per hour.
   (Disagree) 1 2 3 4 5 (Agree)

* Physics Self-Efficacy Survey Adapted from (Shaw, 2004).
Physics Tales 1 – Penning a Powerful Cartoon!

In physics class you have recently learned about the concepts of current, power, and voltage. If you recall, Power = Current x Voltage, or P = IV. Excited to share your new-found physics knowledge with the world, you have decided to pen a physics cartoon to share these concepts with the world. You plan on submitting your illustration for possible submission into ‘The Physics Teacher’ magazine. The guidelines for submission indicate that your cartoon must:

1. Use a creative analogy to clearly convey the P=IV relationship.
2. Help readers visualize that concept through the use of sketches, cartoons, or other visual aids.
3. Include at least 2 calculations as examples.
Because of your physics background, you landed a summer job as an assistant technician for a telephone company in California. During a recent earthquake, a 1.0-mile long underground telephone line is crushed at some point. This telephone line is made up of two parallel copper wires of the same diameter and same length, which are normally not connected. At the place where the line is crushed, the two wires make contact. Your boss wants you to find this place so that the wire can be dug up and fixed. You disconnect the line from the telephone system by disconnecting both wires of the line at both ends. You then go to one end of the line and connect one terminal of a 6.0-V battery to one wire, and the other terminal of the battery to one terminal of an ammeter (which has essentially zero resistance). When the other terminal of the ammeter is connected to the other wire, the ammeter shows that the current through the wire is 1 A. You then disconnect everything and travel to the other end of the telephone line, where you repeat the process and find a current of 1/3 A.

* Adapted from

Physics Tales 3 – The Electrician’s Mystery Medallion!

One day while helping your aunt clean out her basement, you find a strange medallion. Your uncle, a retired electrician, used to wear this odd medallion around his neck every day at work. The medallion contains 12 equations dealing with electricity, but over time, many of the equations have faded. Your aunt, who knows you are taking physics this year, would like to fix it up and give it to your uncle as a surprise gift, but she doesn’t know what the equations should be. You tell her not to worry and you take the medallion home. When your uncle sees his refurbished medallion, he is thrilled.
You are minding your own business riding an elevator on your way to a job interview at Microsoft when the elevator stops suddenly and the clock above the door begins counting down from 15:00. Annoyed, you press the buttons on the panel really hard. The panel door falls off and you realize being stuck in an elevator is the least of your problems. Behind the panel is a ticking time bomb! Upon closer inspection you realize that the bomb is connected to the clock by the circuit shown below. The megacircuit is a network of resistors that are connected in series and parallel. The elevator panel has 4 spare resistors that look like the resistors in the megacircuit. In fact, all the resistors appear to have the same resistance. If you can replace the megacircuit with a simple circuit of the same equivalent resistance (one not connected to a bomb!), you just might trick the bomb into not blowing up. You do not have a calculator, but you realize that you don’t need one. Good luck at your job interview.
A new game is sweeping college campuses across the country. Like Soduko, the game has only a few simple rules. Instead of filling in a grid of numbers, players must analyze a network of resistors in series and parallel and determine the current through, potential difference across and resistance of each resistor. Each Circuito™ puzzle begins with a circuit diagram and a table of V, I, and R values for each resistor. The table is incomplete. Players square off against one another in a race to finish Circuito™. Each puzzle can be solved using only ohm’s law and the rules for calculating equivalent resistance. The game is not just a math game. Patterns of symmetry and logical reasoning allow skilled players to fill in many values without performing calculations. The difficulty of each puzzle varies based on the number of resistors, the symmetry of the problem, and type and amount of initial information. Once you play Circuito™, you’re hooked. Not only can you play the game, you can make design your own Circuito™ puzzles. Having seen the game board below, you decide to design your own Circuito™ board, complete with an answer key, and challenge our friends to a game.

<table>
<thead>
<tr>
<th>Battery</th>
<th>R (ohms)</th>
<th>V (Volts)</th>
<th>I (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>0 ohm</td>
<td>30 V</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>10 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>20 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>10 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>20 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>30 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>50 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>40 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>50 ohm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
With the advancement of medical technologies, it is now possible to perform certain surgeries remotely. A doctor at one location can operate a machine that mimics the motions of a surgeon. This machine then transmits a signal through the internet to another machine at a hospital far away. A machine at the second hospital, hundreds of miles away, receives the signal and a similar machine performs the actual operation. This type of 'telesurgery' was first performed in 2001 in France by a surgeon in New York City (http://en.wikipedia.org/wiki/Remote_surgery). This type of surgery has become more common in Canada, which is a large country with many northern towns that are far from major cities. This technology has made some surgeries possible in these northern towns that would have previously required a long flight to a major metropolitan hospital.

As part of a consulting team for the University of Rochester, you have been asked to explore the possibility of setting up a dedicated connection with the University of Buffalo over a direct connection via copper wire. You have been asked by the group to determine the minimum thickness (gauge), cost, and current required to set up a connection from Rochester to Buffalo. Copper wire must be run 60 miles. The device will use an applied potential difference of 5 V. The Power dissipated by the wire must not exceed 250 mW or it may melt the insulation and cause a short.

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Diameter (mm)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.81 mm</td>
<td>$0.12 per Foot</td>
</tr>
<tr>
<td>18</td>
<td>1.02 mm</td>
<td>$0.17 per Foot</td>
</tr>
<tr>
<td>16</td>
<td>1.29 mm</td>
<td>$0.19 per Foot</td>
</tr>
<tr>
<td>14</td>
<td>1.63 mm</td>
<td>$0.22 per Foot</td>
</tr>
<tr>
<td>12</td>
<td>2.05 mm</td>
<td>$0.25 per Foot</td>
</tr>
<tr>
<td>10</td>
<td>2.59 mm</td>
<td>$0.29 per Foot</td>
</tr>
<tr>
<td>8</td>
<td>3.26 mm</td>
<td>$0.69 per Foot</td>
</tr>
<tr>
<td>6</td>
<td>4.12 mm</td>
<td>$0.79 per Foot</td>
</tr>
<tr>
<td>5</td>
<td>4.62 mm</td>
<td>$0.89 per Foot</td>
</tr>
<tr>
<td>4</td>
<td>5.19 mm</td>
<td>$0.99 per Foot</td>
</tr>
</tbody>
</table>
Physics Tales 7 – Who Needs the Electric Company?

With the price of electricity going up, you are considering supplementing your electricity provider with solar panels installed on your roof. Before making such a radical change, you must determine how much electrical energy your home requires. A convenient unit for measuring electrical energy is the kilowatt hour, kwh. One kwh is equivalent to a power of 1000 W for one hour. It is also the equivalent of 1 W for 1000 hours. You estimate the number of kilowatt hours of energy used by your house in one month. Assume that electricity is sold at $0.10/kwh.

A solar panel can usually collect about 15% of the solar energy that strikes the panel. Obviously, this only works during the day time. Given our latitude and average daily weather, we can assume that that approximately 300 w/m² of solar energy strikes your 200 m² roof. You would be able to fit usable solar panels onto about 30% of your roof. Any electricity you generate beyond what you need, can be sold back to the electric company at $0.10/kwr.
**Concept Test Questions**

* Concept Test Question # 1

A constant potential difference $V$ is applied across two resistors connected in parallel as shown.

The current through the $2 \, \Omega$ resistor is 2 A. What is the current through the $4 \, \Omega$ resistor?

- A. 0 A
- B. 1 A
- C. 2 A
- D. 4 A
- E. Need to know the potential difference.

* Concept Test Question # 2

Charge flows through a light bulb. Suppose a wire is connected across the bulb as shown. When the wire is connected,

- A. all the charge continues to flow through the bulb.
- B. half the charge flows through the wire, the other half continues through the bulb.
- C. all the charge flows through the wire.
- D. none of the above.

* Concept Test Question # 3

Rank resistors A, B, and C from highest to lowest V.

Appendix 10
Concept Test Questions

* Concept Test Question # 4

The circuit below consists of two identical light bulbs burning with equal brightness and a single 12 V battery. When a wire is added as shown, the brightness of bulb A

A. Increases
B. Decreases
C. Remains the Same
D. Need to know more

* Concept Test Question # 5

Consider the Y-shaped tube shown below. Suppose 2 balls per second are stuffed into the opening at A. The number of balls per second that come out of the tube at B is

A. always equal to 2
B. always smaller than or equal to 2
C. always larger than or equal to 2
D. equal to 1
E. depends on what happens at C

Concept Test Question # 6

A resistor dissipates 100 J/s when connected in a circuit. If the voltage across the resistor remains the same, and the current is doubled, the resistor will dissipate:

A. 100 J/s
B. 200 J/s
C. 200 W
D. 400 W

Concept Test Question # 7

A battery maintains a 25 V potential difference across a 100 ohm light bulb. If the battery is replaced with a 50 V battery, the brightness of the bulb will

A. halve.
B. stay the same.
C. double.
D. quadruple.
Concept Test Questions

* Concept Test Question #8

Consider two identical resistors wired in series. If there is an electric current through the combination, the current in the second resistor is

A. equal to  
B. half  
C. smaller than, but not necessarily half

* Concept Test Question #9

As more identical resistors, \( R \), are added to the parallel circuit shown here, the total resistance between points \( P \) and \( Q \)

\[ R \]

A. Increase  
B. Remain the same  
C. Decrease

Concept Test Question #10

Each resistor in the circuit shown below has a resistance of 5 ohms and the batter maintains a potential difference of 5 volts. What is the equivalent resistance of the circuit?

\[ \]

A. 2.5 ohms  
B. 5 ohms  
C. 10 ohms  
D. 40 ohms  
E. More information is needed

Concept Test Question #11 (Same figure as question 10)

The potential difference across resistor A is

A. \( 5/8 \) V  
B. 2.5 V  
C. 5 V  
D. Other
Concept Test Questions

* Concept Test Question # 12

The circuit that emits the most light is

A. I.
B. II.
C. The two emit the same amount of light.

* Concept Test Question # 13

The three light bulbs in the circuit all have the same resistance. Given that brightness is proportional to power dissipated, the brightness of bulbs B and C together, compared with the brightness of bulb A, is

A. twice as much.
B. the same.
C. half as much.

* Concept Test Question # 14

If a second battery is added in a series as shown in (b), how many of the following change? The current \( I \) at A, the potential difference \( V_{AB} \) between A and B, the resistance \( R \) of the light bulb.

A. All three.
B. Two.
C. One.
D. It depends.

* Concept Test Question # 15

Two 1.5 V batteries are connected as shown below. The voltmeter should read

A. 1.5 V
B. 3 V
C. 0.75 V
D. 0 V

Student Response Cards

ABC D

?  

Trick Question

Agree  Disagree

Appendix 14
Concept Test Survey

Concept test questions are questions that appear on screen during lecture with multiple choices. Think about how these questions have been used during class. For each statement please circle the number that best represents your level of agreement. There are no right or wrong answers, and your answers will not affect your grade. I will be using this anonymous survey in my research study to evaluate the use of Concept Test questions in our class and to decide how to use these questions in the future.

1) Concept Test questions help me understand physics better.

   (Disagree) 1 2 3 4 5 (Agree)

2) I frequently learn from my peers when discussing a Concept Test question.

   (Disagree) 1 2 3 4 5 (Agree)

3) Discussing a Concept Test question with my peers increases the likelihood that I will get the correct answer.

   (Disagree) 1 2 3 4 5 (Agree)

4) I learn more when I discuss a Concept Test question with my peers than when I do not discuss the question.

   (Disagree) 1 2 3 4 5 (Agree)

5) I am more likely to share my thoughts with the class after discussing a Concept Test question with a peer.

   (Disagree) 1 2 3 4 5 (Agree)

6) Explaining the answer to a Concept Test question helped improved my understanding.

   (Disagree) 1 2 3 4 5 (Agree)

7) I would rather hear the answer to a Concept Test question immediately from the teacher, than spend time discussing the question with my peers.

   (Disagree) 1 2 3 4 5 (Agree)

8) I think Concept Test questions are an inefficient use of class.

   (Disagree) 1 2 3 4 5 (Agree)

9) I would learn more with less concept tests and more time devoted to lecture.
Concept Test Survey

(Disagree) 1 2 3 4 5 (Agree)

10) What did you like about Concept Test questions, and your discussions of the questions with your peers?

11) What did you dislike about Concept Test questions and your discussions with your peers?

12) What do you think could be done to improve the way we use Concept Test questions?

13) Is there anything else you would like to say?
Context Rich Problem Survey

In this unit we worked on a number of context rich problems, which we called Physics Tales. I have given you a blank copy of the context rich problems from this unit. Please take a few minutes to look at each task.

Each context rich problem has an ID at the top of the page. For each category below please list each context rich problem by ID from Most to Least.

**Difficulty** – How challenging did you find this problem to complete.

**Interest** – How interesting was this problem to you.

**Educational Value** – How valuable did you find this problem? Did learn a lot from this problem? Do you think future students would learn from this problem?

**Recommended for Future** – How strongly would you recommend that this problem be used next year?

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(Over)

Appendix 17
Context Rich Problem Survey

1) What did you like about completing these context rich problems?

2) What did you dislike about completing these problems?

3) How did working in a group on these problems differ from working alone?

4) Do you think you learned more by working in a group on these problems, that you would have working alone?

5) What helped or would have helped your group be productive?

6) What advice do you have for future groups?

7) What advice do you have for future tasks?
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Concept Test Survey Question 10: What did you like about Concept Test questions, and your discussions of the questions with your peers?

Comment # 1 (CT Rating = 5.00) Helps represent what will be on tests.
Comment # 2 (CT Rating = 4.89) It provided insight that may not have been given by the teacher.
Comment # 3 (CT Rating = 4.78) Helps me to better remember and understand the problem by hearing my peers thoughts.
Comment # 4 (CT Rating = 4.67) sense of accomplishment on getting the answer right. - It was like a game.
Comment # 5 (CT Rating = 4.67) Having arguments with [students] about everything but learning a lot.
Comment # 6 (CT Rating = 4.44) It helped me understand things better * helped me notice things I wouldn't have noticed before.
Comment # 7 (CT Rating = 4.22) It keeps us active in participating. Everyone gets a chance to answer.
Comment # 8 (CT Rating = 4.11) Gave me an opportunity to understand more easily.
Comment # 9 (CT Rating = 4.11) Learning about the right answer.
Comment # 10 (CT Rating = 4.00) Diversity in ways to learn.
Comment # 11 (CT Rating = 4.00) I feel like I remember the concepts because you are force to answer and participate.
Comment # 12 (CT Rating = 4.00) It puts what we learn in lecture into action.
Comment # 13 (CT Rating = 3.89) Interactive.
Comment # 14 (CT Rating = 3.89) I liked that we got the chance to discuss the question before we heard the answer because it promotes active learning.
Comment # 15 (CT Rating = 3.78) I like how I can form my own opinions, and then compare them with other students.
Comment # 16 (CT Rating = 3.78) To see their point of view.
Comment # 17 (CT Rating = 3.78) It allowed you to discuss different thought processes among your peers.
Comment # 18 (CT Rating = 3.78) It forced me to do more on my own and learn it better.
Comment # 19 (CT Rating = 3.78) Like that we discussed answer with teacher after.
Comment # 20 (CT Rating = 3.67) I like how the questions get you thinking and give you possible answers that most conser. They help me learn and remember the correct answer.
Comment # 21 (CT Rating = 3.56) They were simple and helped with the topic.
Comment # 22 (CT Rating = 3.44) They make me think more. I am an active learner and it helps to do the problem, not just watch.
Comment # 23 (CT Rating = 3.33) I like them because they reinforce what you're talking about in lecture.
Comment # 24 (CT Rating = 3.22) Just that you can try the question and see from others how they came up with their answer.
Comment # 25 (CT Rating = 3.11) Helps me understand better. Have a break from just lecture so you can think exclusively about the concept.
Comment # 26 (CT Rating = 3.11) I learned information that is interesting.
Comment # 27 (CT Rating = 2.89) Sometimes explanations of students make more sense to me than the teacher's!
Comment # 28 (CT Rating = 1.78) It seemed somewhat useless, I think graded take home/ inclas assignments would be better.

Concept Test Survey Question 11: What did you dislike about Concept Test questions and your discussions with your peers?

Comment # 29 (CT Rating = 4.78) Not being able to discuss our ideas before choosing an answer.
Comment # 30 (CT Rating = 4.67) It was frustrating not knowing the answer.
Comment # 31 (CT Rating = 4.22) I don't dislike anything, oh wait, I don't like trick questions.
Comment # 32 (CT Rating = 4.11) The questions were kind of annoying. Good idea though.
Comment # 33 (CT Rating = 4.11) Sometimes no one knows, and it can waste time.
Comment # 34 (CT Rating = 4.00) Too slow.
Comment # 35 (CT Rating = 4.00) When you were the only one with a certain answer.
Comment #36 (CT Rating = 4.00) Sometimes they would get drawn out with all the discussing.
Comment #37 (CT Rating = 3.89) It sometimes is not necessary.
Comment #38 (CT Rating = 3.78) I didn't really have any problems with these.
Comment #39 (CT Rating = 3.78) It takes up time.
Comment #40 (CT Rating = 3.78) Sometimes they led to disagreements and more confusion between peers.
Comment #41 (CT Rating = 3.78) Sometimes I didn't have enough time to answer the questions.
Comment #42 (CT Rating = 3.78) Disliked spending too much time discussing with peers and too much time asking one person to explain their answer.
Comment #43 (CT Rating = 3.67) When discussing with peers I would sometimes get confused when what they're saying is wrong.
Comment #44 (CT Rating = 3.56) Having to discuss our answer with our 'peers'.
Comment #45 (CT Rating = 3.44) Sometimes it takes up too much time.
Comment #46 (CT Rating = 3.33) I'd rather have you skip the discussion with peers. I want to hear the answer straight from you.
Comment #47 (CT Rating = 3.22) We did so many of them.
Comment #48 (CT Rating = 3.11) I learn better through lecture.
Comment #49 (CT Rating = 2.89) Slightly demoralizing considering I couldn't do a lot of them.
Comment #50 (CT Rating = 1.78) Just about everything.

Concept Test Survey Question 12: What do you think could be done to improve the way we use Concept Test questions?

Comment #52 (CT Rating = 4.89) Perhaps offering more time per question.
Comment #53 (CT Rating = 4.67) Um. I really like them. So nothing.
Comment #54 (CT Rating = 4.44) I think the concept test questions were good the way they are.
Comment #55 (CT Rating = 4.22) Use them more often.
Comment #56 (CT Rating = 4.11) Use fun activities to do them more hands on learning helps us want to learn.
Comment #57 (CT Rating = 4.11) Make them quicker.
Comment #58 (CT Rating = 4.00) A little faster.
Comment #59 (CT Rating = 4.00) Less calculations.
Comment #60 (CT Rating = 3.89) Make the questions more active.
Comment #61 (CT Rating = 3.78) Discuss more with the class.
Comment #62 (CT Rating = 3.78) Everyone gets a partner so they can work through it together more officially.
Comment #63 (CT Rating = 3.78) Maybe instead of just doing specific problems, we could discuss ideas/definitions/themes.
Comment #64 (CT Rating = 3.67) Once people give their 1st answer, eliminate one of the wrong choices and see how many people have to change their answers.
Comment #65 (CT Rating = 3.44) More of them, but move on a worksheet to do. I like to go into a test knowing that we practice EVERY type of question.
Comment #66 (CT Rating = 3.22) Only do like two every other day or something.
Comment #67 (CT Rating = 2.89) Have cards not all be the same color, I could always tell other people's answers in front of me, based on the color of the back of the card.
Comment #68 (CT Rating = 1.78) Not do them.
Comment #69 (CT Rating = 1.78) Don't do them.

Concept Test Survey Question 13: Is there anything else you would like to say?

Comment #70 (CT Rating = 4.78) I like concept test questions because they usually show up on the test and I remember doing them in class rather than just listening to lecture.
Comment #71 (CT Rating = 4.67) These are my favorite part of class. It's like a game. Pretty fun. The electron configurations [Student Roles] were fun too.
Comment # 72 (CT Rating = 4.00) Sometimes it would be better to just hear the answer and then discuss with peers to explain how to solve it to people what got it wrong. I like concept tests.

Comment # 73 (CT Rating = 3.78) They were a valuable use of time.

Comment # 74 (CT Rating = 3.78) The cards were very nice!

Comment # 75 (CT Rating = 3.67) I like them.

Comment # 76 (CT Rating = 3.44) I like the questions a lot, very helpful.

Comment # 77 (CT Rating = 1.78) You should show more videos demonstrating the concepts you're talking about, I think visualizing it makes all the difference.

Comment # 78 (CT Rating = 1.78) More pictures, video and other media.

Context Rich Problem Survey Question 1: What did you like about completing these context rich Problem?

Comment # 79 Getting it right.

Comment # 80 They helped demonstrate these principles in the real world.

Comment # 81 Learning physics in a way that is relevant to the real world.

Comment # 82 I liked being the skeptic or the manager. That was fun. I liked the nonconventional way of solving the problems.

Comment # 83 Challenging.

Comment # 84 Helped me get ready for the test.

Comment # 85 Challenging.

Comment # 86 Got to work with different people in the class.

Comment # 87 Working in a group.

Comment # 88 Harder than normal questions.

Comment # 89 Working in a group was fun.

Comment # 90 A couple were interesting, but most were just a lot of work.

Comment # 91 We got to work in groups.

Comment # 92 Interesting to apply concepts to life like problems.

Comment # 93 They helped with concepts.

Comment # 94 The Team work Part.

Comment # 95 They were fun and educational.

Comment # 96 Got to work in groups to complete challenge.

Comment # 97 Worked in groups.

Comment # 98 They made you think hard and work with other's ideas.

Comment # 99 Answers usually made sense about the end.

Comment # 100 They helped me think on the problem to understand a topic.

Comment # 101 I liked being able to work with different people.

Comment # 102 It was good to be in a group.

Comment # 103 Usually a challenge understanding a concept.

Comment # 104 We learned in a social environment.

Comment # 105 Seriously? Not much. It wasn't really fun but I understand why we had to do them.

Comment # 106 Nothing really, tons social loafing.

Context Rich Problem Survey Question 2: What did you dislike about completing these problems?

Comment # 107 Everything.

Comment # 108 They were frustrating at times.

Comment # 109 They were challenging, need more background info.

Comment # 110 Sometimes the task was confusing. How to start was confusing.

Comment # 111 Unproductive group.

Comment # 112 They were hard.

Comment # 113 I did not like my group.

Comment # 114 They didn't really try to explain anything to me.

Comment # 115 Social loafing.

Comment # 116 Some were a tad corny.

Appendix 22
Comment # 117 They took longer than they should have.
Comment # 118 Very difficult sometimes.
Comment # 119 Working with certain individuals
Comment # 120 They took a long time.
Comment # 121 They were confusing in some instances.
Comment # 122 Often times I didn't understand how to do them and found that just one person was doing the work.
Comment # 123 They were hard. We just learned the information.
Comment # 124 Some seemed very hard and a lot to take in.
Comment # 125 They took way too long and some were useless because the concept was so easy sometimes that you could of told me.
Comment # 126 Nothing, I thought they were a welcome break from lecture.
Comment # 127 Took all of class.
Comment # 128 There was a lot of reading, and the difficulty was high.
Comment # 129 My group didn't like to work.
Comment # 130 The work involved.
Comment # 131 The work.

Context Rich Problem Survey Question 3: How did working in a group on these problems differ from working alone?

Comment # 132 Other input.
Comment # 133 It provided differing view points.
Comment # 134 I liked working in a group because we could build our ideas of each other. Everyone contributed something different.
Comment # 135 Much easier. You could throw ideas off of each other.
Comment # 136 helped bounce ideas off of each other.
Comment # 137 my group members help me understand better.
Comment # 138 Get other ideas.
Comment # 139 Discussed answers and got better answers.
Comment # 140 discuss ways to complete problem.
Comment # 141 new ideas, think more, more organized.
Comment # 142 It was at times beneficial, but at other times overkill.
Comment # 143 Two heads are better than one.
Comment # 144 feeling like I didn't have enough information at the beginning
Comment # 145 Less work, more minds
Comment # 146 More discussion and understanding.
Comment # 147 Helped develop new ideas and theories.
Comment # 148 Varies by question.
Comment # 149 Made it easier.
Comment # 150 Working in a group helped. Hard questions need other people's input.
Comment # 151 Everyone had more to contribute and learn.
Comment # 152 Sometimes group work takes way too long.
Comment # 153 It was good because you could ask for help and pool brains.
Comment # 154 You get more ideas from people.
Comment # 155 Multiple Inputs.
Comment # 156 Two heads are better than one.
Comment # 157 More opinions.
Comment # 158 It sort of prolonged it.
Comment # 159 More people, more different ways.

Context Rich Problem Survey Question 4: Do you think you learned more by working in a group on these problems, that you would have working alone?

Comment # 160 yes
Comment # 161 From time to time, individuals in a group offer help; although, working alone may be
Comment # 162 Yes
Comment # 163 Definitely, because you would have to convince the other team members that your point was right. You really had to know your stuff.
Comment # 164 Not really, I had to shoulder the group.
Comment # 165 Yes
Comment # 166 Definitely
Comment # 167 Yes.
Comment # 168 yes
Comment # 169 I believe I did.
Comment # 170 A little bit.
Comment # 171 About the same.
Comment # 172 realize you're not the only one who doesn't know what's going on
Comment # 173 Yes
Comment # 174 yes I did.
Comment # 175 Yes.
Comment # 176 Briefly learning how to do more complex problems similar to the physics tales so I had something to start with.
Comment # 177 Yes
Comment # 178 Yes - Questions were hard - need other people's ideas to work off of.
Comment # 179 Yes - someone in the group typically moved forwards an answer which helped big.
Comment # 180 No
Comment # 181 Yes.
Comment # 182 yes.
Comment # 183 Yes
Comment # 184 Probably about the same.
Comment # 185 Probably.
Comment # 186 Actually yeah...
Comment # 187 No.

Context Rich Problem Survey Question 5: What helped or would have helped your group be productive?

Comment # 188 Couldn't tell you.
Comment # 189 If we had picked our own groups.
Comment # 190 Knowing the lab was collected.
Comment # 191 Hmm, I don't know. Maybe a larger group. It was hard when several people in the group didn't contribute.
Comment # 192 If we didn't have a certain group member.
Comment # 193 Read the problems over twice, take notes.
Comment # 194 Unproductive group members.
Comment # 195 grade
Comment # 196 We just never got off task, good group management.
Comment # 197 Better participation from the whole group.
Comment # 198 Less fooling around.
Comment # 199 no, the explanation at the end was more helpful
Comment # 200 More effort.
Comment # 201 More members.
Comment # 202 More guidelines
Comment # 203 Try to learn from what people in the group are saying if you don't understand.
Comment # 204 Skipping some
Comment # 205 nothing really.
Comment # 206 I think we were productive already.
Comment # 207 Less talking and fooling around.
Comment # 208 Different members.
Comment # 209 Not having a certain group member.
Context Rich Problem Survey Question 6: What advice do you have for future groups?

Comment # 210 Get work done.
Comment # 211 Work together and listen to others.
Comment # 212 Don't always go for the obvious answer, but don't talk yourself out of the right answer.
Comment # 213 Read the problems carefully and work together.
Comment # 214 Talk to groups around you for advice.
Comment # 215 Have your pencils and calculators with full batteries.
Comment # 216 Different groups every time
Comment # 217 Have good group management.
Comment # 218 Make sure they're groups of 3 (ours was 4).
Comment # 219 Work hard, play harder!
Comment # 220 More information, but less convoluted
Comment # 221 Work together
Comment # 222 Stay on task.
Comment # 223 These are fun and help your concepts of electricity.
Comment # 224 Use your reference table.
Comment # 225 Work with each other and put ideas together and work with what you've got.
Comment # 226 Think more out loud.
Comment # 227 Come up with a common idea.
Comment # 228 Work hard and have fun.
Comment # 229 Skip class, or go to the library.

Context Rich Problem Survey Question 7: What advice do you have for future tasks?

Comment # 230 Get work done.
Comment # 231 Maybe something more abstract? I love the creative ones it makes it easier to do the problem when you can use your imagination.
Comment # 232 Make them a teensy bit easier.
Comment # 233 Talk about the tasks before.
Comment # 234 Make it more fun.
Comment # 235 None.
Comment # 236 Maybe have them be graded.
Comment # 237 Make them less difficult.
Comment # 238 It's ok to get frustrated, I'm pretty sure that was part of the point.
Comment # 239 Think it through.
Comment # 240 Give more information.
Comment # 241 Keep on developing new and interesting tasks.
Comment # 242 Make it a contest, have a winner or something.
Comment # 243 Offer candy bonus.
Comment # 244 Only stick to the most difficult tasks.
Comment # 245 Make sure they are intellectually stimulating but at the same time not too hard.
Comment # 246 Make it challenging, but keep it interesting.
Comment # 247 Make them easier.
Comment # 248 Video based.