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Application of peer instruction in the high school setting

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APPLICATION OF PEER INSTRUCTION IN THE HIGH SCHOOL SETTING

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Abstract

This study investigates whether the response component of Peer Instruction can be successfully added to my normal classroom instruction creating higher gains in student conceptual understanding of force concepts. This action research is intended to analyze this goal for possible application in any regular high school Physics classroom, using myself as a case study. The Force Concept Inventory was used as a pretest/posttest determinate of the learning gains of 85 students spread through four regular Physics classes during the 2009-10 school year. Forty-Two of these students were used as an experimental group where the response component of Peer Instruction was added to regular classroom instruction. The balance of these students was used as a control group.

Statistically, it was not determined that there is a positive correlation between the response component of Peer Instruction and force concept learning gains, yet some positives for implementing Peer Instruction were observed. The communication developed between the students and myself, the transfer of focus to a more student-centered environment and the enhancement of cognitive analysis by the student were strong indicators for continued study.

Introduction

As I begin each year, laying down the foundation of motion, it never fails to amaze me the simple concrete level with which I have to begin with my senior level students. I begin by pointing out an object in the room and asking, “Where is it?” To which they always reply, “Right there!!” I then ask, “where is ‘there’?” to which they generally reply “right there!!” We volley back and forth, the class basically answering my question in every form they can muster yet not realizing the depth or accuracy their answers lack. They think I am asking for an “answer” when in reality I am asking for them to express a cognitive thought. I allow this process to continue until at least half the audience begins to realize that I am looking for more than they are accustomed to giving. Frustration begins to occur. A few wonder if they have been assigned to the old guy that has lost his faculties. I will admit that there might be at least a tinge of the sadistic in my approach here but experience has shown me that if my students are always comfortable they rarely learn. If they are always successful in everything they attempt, they will lack depth. My ultimate goal is not about the object but can they quantifiably and qualitatively tell me “where it is at?” From here I begin to deconstruct their thoughts to discover the basis for their answer “right there.” I have to show them the need for a reference point out of which we can define position. It would seem that this activity performed at the beginning of the year would suffice to enlighten them on the need for reevaluating the process that they use as scientists. It is overly apparent that most students naturally enter my classroom lacking the skills, understanding or perhaps drive to problem solve in a correct manner i.e. to be good scientists.

How many of us have been told by a small child, “I can do it” when we attempt to teach them something new, only to observe their failure due to the fact that they had no more than a rudimentary understanding of what they were trying? How many teenagers desiring greater freedom, ask for things they are not responsible enough to handle, i.e. their own car? In general, we tend to think on a concrete level until we are forced to develop deeper cognitive processes. My ten year old daughter for example has started asking her mother and me if she can join a baby-sitting class with her friend. Aside from the fact she is at least partially motivated by her desire to just spend time with her friend, she does see this as an opportunity to make some money. What is eye-opening to me is the fact that as we discuss the responsibilities involved it becomes quite apparent that she sees "baby-sitting" as little more than playing with her dolls. The facts of the responsibility of having the welfare of another person are totally lost on her. Where she sees an opportunity to play dress-up and "feed the baby," her mother and I realize the stress of caring for a child. At ten years old, this is understandable in her thought process, but if she were seventeen I would worry. It would seem that my students at this senior level of secondary education should have at least begun defining the process of evaluating an everyday situation. Unfortunately, many times they enter my classroom with the same lack of process as my ten year old.

For 2000 years, the conclusions we have drawn from our simple observations of the world around us have led us to the wrong answers. The earth looked flat and so flat it must be. We looked outward from the borders of our planet and watched the cosmos encircle us, so we must be at the center of all things (Not to mention that man in general is an extremely egocentric being). According to Aristotle if an object falls this motion is natural since, in his mind, all things returned back to their "natural state." Yet if the motion is in a direction other than down and due to the coercion of some other object (i.e. bat hitting a ball) the motion is "violent" and unnatural. In his mind, for the object to have continual horizontal motion, there must be a constant impetus. This lead him to theorize that as the ball moves forward through the air that it creates a vacuum and as the air rushes around the object to fill the void, it pushed the object forward.

Today my students are still captured by this sand trap of simple thinking. They allow their preconceived ideas to dissuade them toward a simplistic understanding of the world that surrounds them. If a ball moves forward something must be pushing it because it was the push that got it going. In their experience if one stops pushing the object, it stops. They fail to take into consideration the whole body of information available such as “Why does an object moving on a smoother surface move farther before it stops?”

Aristotle held that the rate of motion was directly related to the force on the object and inversely proportionate to the resistance of the medium it moved through.

$$V=F/R$$

(V=velocity of the object, F=force acting on it, R=resistance of medium.)

Through my experience I would say that most of my students would quickly agree with this summation. If they would relate the dynamics of this equality to what they observe in multiple possibilities, the relation begins to fail. Their conclusions are so quickly based in their immediate assumptions, they fail to contemplate how these variables directly influence one another.

Albert Einstein and Leopold Infeld spoke to exactly the same fallacies that I see infecting the students who enter my classroom**:** (Einstein)

> To understand these phenomena it is wise to begin with the simplest possible cases, and proceed gradually to the more complicated ones. Consider a body at rest, where there is no motion at all. To change the position of such a body it is necessary to exert some influence upon it, to push it or lift it, or let other bodies, such as horses or steam engines, act upon it. Our intuitive idea is that motion is connected with the acts of pushing, lifting or pulling. Repeated experience would make us risk the further statement that we must push harder if we wish to move the body faster. It seems natural to conclude that the stronger the action exerted on a body, the greater will be its speed. A four-horse carriage goes faster than a carriage drawn by only two horses. Intuition thus tells us that speed is essentially connected with action.

It is a familiar fact to readers of detective fiction that a false clue muddles the story and postpones the solution. The method of reasoning dictated by intuition was wrong and led to false ideas of motion which were held for centuries. Aristotle's great authority throughout Europe was perhaps the chief reason for the long belief in this intuitive idea. We read in the Mechanics, for two thousand years attributed to him:

The moving body comes to a standstill when the force which pushes it along can no longer so act as to push it.

The discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought and marks the real beginning of physics. This discovery taught us that intuitive conclusions based on immediate observations are not always to be trusted, for they sometimes lead to the wrong clues.

Historical Perspective

Probably the most comprehensive research material on the study of student understanding of Physics comes from the Physics Education Group (PEG) at the University of Washington headed by L.C. McDermott. This group has forged great gains in the advancement of our understanding of the acquisition of simple motion concepts by introductory level college students. Concisely stated, the problem is that:

> Physics instructors generally share a common interpretation of the kinematical concepts based on operational definitions and precise verbal mathematical articulation. On the other hand, students in an introductory physics course are likely to have a wide variety of somewhat vague and undifferentiated ideas about motion based on intuition, experience, and their perception of previous instruction. (Trowbridge 1980)

A common methodology of PEG was to have students observe the demonstration of a physics concept. Afterward the student would be interviewed to ascertain their ability to apply the "concept to the interpretation of simple motions of real objects" (Trowbridge 1980). From these interviews, the researchers catalogued many misconceptions held by physics students about motion and how the motion of an object is related to the forces acting on it.

In two linked studies, McDermott and David E. Trowbridge interviewed students' pre and post instruction on their perception of objects undergoing Piagetian motion using speed comparison tasks. These students were chosen from the University of Washington from differing levels of instruction, compensatory (academically disadvantaged) to calculus based.

In the first study (Trowbridge 1980) which focused primarily on velocity in one dimension, a result that was overly apparent was the lack of students to differentiate between like terms such as velocity and position. As such students were found to confuse the comparison of the velocities of two objects with their positions (i.e. an object must be going faster if it is ahead of another object; or the two objects are at the same speed when they are at equal positions).

In the second study (Trowbridge 1981) PEG uncovered a common student misconception as the influence of final velocity and position on acceleration. Students believed that objects must have the same acceleration if they ended at the same position at the same time even though the objects were clearly shown to have different displacements and start times. Other students agreed with this finding but based it on the fact that both balls ended at the same velocity. These student misconceptions were not only prevalent pre instruction but continued post instruction, even by students who had successfully completed the calculus- based course. These misconceptions were even more surprising in light of the fact that many of these students could define the concepts of velocity and acceleration in relation to what had been taught to them (i.e. velocity is displacement during time, acceleration is a changing velocity as time passes.)

A second misconception about acceleration was that students confused average velocity with final velocity in the calculation for Δv.

> …The difficulty illustrated proved to be widespread among all student populations included in this study. Students would often write v=d/t and a=v/t, proceed to calculate average velocity on the incline, and then use this value, instead of instantaneous velocity at the end of the incline, to find the acceleration. This confusion made successful solution of the problem impossible. Moreover, discrimination between instantaneous velocity and average velocity is essential for as numerical interpretation of Δv, which in turn is crucial for an understanding of acceleration. (Trowbridge 1981)

A third task developed to ascertain the students' understanding of uniform acceleration when velocity is undergoing constant change showed a consistent belief that the acceleration of the object was tied directly to the velocity of the object. Students observed a ball rolling up an incline which eventually reverses direction and rolls down the incline. When the highest point in the ball's motion is highlighted by the interviewer it was noted that students responded that the ball's velocity would equal zero so its acceleration must also be zero. Many times the response was based on their belief that the sign of the acceleration would change with the sign of the velocity (positive going up and negative going down) and as such this value must pass through zero.

In addition to cataloging students' difficulties in understanding kinematic relationships, the PEG group has also investigated student's misconceptions of how forces affect the motion of an object. In 1987 McDermott, along with Ronald A. Lawson (Lawson 1987), surveyed volunteer, post instruction students on their application of the impulse-momentum theorem when two objects of vastly differing masses were shown to receive equal force over different time intervals. One glaring trend was that none of 16 non-calculus students correctly compared the objects' change in momentum and/or were able to correctly explain their comparison. Only 4 of 12 calculus students completed this task correctly. Of equal note, when a student incorrectly surmised that the momenta of each object was the same, by far the most common justification was termed by the authors as the "compensation argument." In essence since the objects' momentum is the product of its mass times its velocity and the larger mass moves slower, the student assumes the product of each must balance out. The student further supports this explanation by stating that the objects received equal force ignoring the need for the force to be integrated in relation to the time it acts on the object to correctly describe the change in the object's momentum. Many times it is not that the scope of the problem that is beyond our students' abilities but the mere fact that they ignore the more subtle dynamics. In my experience, I find that students tend to focus on the "wow" dynamics of demonstration (i.e. force) and causing shortsightedness to other factors of equal importance.

In the second half of that same article (Lawson 1987), students were also asked to comment on the comparison of the kinetic energy of each object. The main purpose here was to ascertain if the students could correctly reason that an equal amount of work was done on each object since the force on each object occurred over the same displacement. One-third of all students (calculus and non-calculus) incorrectly used the same “compensation argument” to explain why more work was done on the lighter object. In general they would argue that the lighter object was moving faster, and since the velocity is squared ($KE = 1/2mv^2$) it must have the greater effect. Since the final velocity of each object was unknown, this would suggest that the student is again thinking in terms of the definition of Kinetic Energy and its formula yet lacking the ability to accurately apply these to describe how the forces acting on an object change its momentum and energy. The idea of work and its relation seem lost on the student.

Even when the student is directly asked about the role of work in the transfer of kinetic energy to the object:

> Interviewer: Have you ever heard of the term work? Do you remember what the word means in Physics?
>
> Student: Work was …the change in Kinetic Energy…or, um, let me think here…I think it might have been the force times…I’m not sure, I think I recall the formula R, F, the cosine of the angle between the two. But we just did problems on that and I can’t remember exactly.

The student seems to have an overdependence on the definition, the formula, and key phrases about the subject, but little understanding of how the definitions interact within a physical scenario. It is important to remember that these students were post-instruction, and when their grades were compared, their overall scores ranked in the upper half of the class. Also if these students were not asked to justify their answers, the author noted that many would be viewed as correct and it would have been assumed that they had understood the concept in the demonstration.

A second interview with a different student, when asked directly about work, defines it correctly "force applied times distance." This student realizes that the force applied and the displacement of both objects is equal, states then that the work on the objects is equal, even directly associates work performed with change in Kinetic Energy, "…but the velocities and the masses are different so they (the kinetic energies) are not necessarily the same." McDermott et al goes on to note "…had the interview been terminated any earlier than it was, the impression would have been that the student's understanding was adequate. After all, almost everything said was correct. It was only by continuing to probe her responses that the investigator was able to determine that the student did not actually make the connection between the work-energy theorem and the moving pucks. Unlike a Physicist, the student did not see the demonstration in terms of a direct application of the formula to the real world." This result highlights that even students who are able to choose the correct answer on a multiple choice physics test may still lack the ability to correctly explain why the answer is correct.

J. Clement published a series of articles depicting the preconceptions that students rely on as they try to understand the conceptual basis of our instruction about motion.

In one study (Clement 1989) he administered a diagnostic test to pre-physics high school students. Each student not only answered the questions but also stated how confident they were in their answer. Clement noted that a consistent misunderstanding among students (75 % of respondents) is that static objects cannot or will not exert a force such as when a cup is placed on a table. I have noted this misconception within my own classroom. The student intuitively believes that gravity still exists on the cup pulling it downward and they seem to realize that this effect of gravity is being countered, but this does not lead many students to correctly diagnose that a normal force must be originating from the table. The conceptual understanding of force by the student is based in the definition "push or pull," and these students have a hard time intuitively seeing a table "pushing" the cup since the cup does not move or the table move when the cup is removed. These students connect “pushing” with moving.

This misconception was found in a second scenario where students were asked to explain why a puck sliding across a floor would stop. Again 39 % of the students said the floor did not exert a force on the puck with the highest confidence of answers. Another 36 % said with slightly less confidence that there was a force from the floor but it had no direction. Only 22 % of the respondents answered correctly but with an overall low belief score.

From an earlier study Clement (1987), supported by Bransford and Donovan (2005), Trowbridge (1981) and McDermott (1990), showed that not only are our students perceptions clouded by the misguided observations already obtained prior to our class, these preconceptions are quite persistent in students’ explanations and must be directly dealt with before the student can grasp a true understanding of the conceptual basis of the material. It was noted that students in a one-on-one tutoring session became incredulous when directly confronted with a physicist’s point of view if it directly counters the student’s strongly held belief. What does this say about the number of times the student, whether consciously or not, ignored instruction because of a previously held belief. Clement continued that these preconceptions can persist in students post Physics instruction at times without evolution.

Clement as well as Espinosa (2005) and Wisner (1983), relay an interesting argument that student misconceptions of motion concepts are paralleled to Aristotelian views of motion which “… support the idea that some preconceptions have common intuitive roots derived“ wrongly “from everyday experience.” (Clement 1987)

> It seems entirely feasible that students at a pre-instructional level may also have difficulties understanding action-at-a-distance, and so conclude that the cause of an object's continual motion rests in itself. (Espinosa)

This view can be traced back to Aristotle himself and the misconception caused continual strife throughout the development of Physics. It emphasizes the effect of isolated observation thinking within "...Student's understanding of mechanics prior to instruction has been strikingly similar to the historical findings about views of motion held previously" (Espinosa) and their historical parallels.

What Have We done?

Is this a new problem? I think not. In most of the literature I reviewed one consistent fact was stated: Traditional lecture alone lacks the needed impact to address these problems. It does not change preconceived ideas nor does it equip our students with the critical thinking inherent to successful understanding of the world around them. It does not make them better scientists. I feel this is a strong contributing factor in their immature, intuitive approach to science reasoning. In the article by Bransford and Donovan (2005), the authors outlined three emerging national goals from the National Research Council and the American Association for the Advancement of Science

> "...for creating more effective science education. The new guidelines include an emphasis on helping students develop (1) familiarity with a discipline's concepts, theories and models; (2) an understanding of how knowledge is generated and justified; and (3) an ability to use these understandings to engage in new inquiry."

The authors present these goals in actual contrast to traditional methodology of instruction even though said methods, (i.e. the acquisition of facts/ knowledge through presentation of lecture/text and the development of thought through the vehicle of "the scientific method") would seem to coincide perfectly with the intent of these goals. Case in point the authors show that even the application of "the scientific method," under historical pretext, becomes nothing more than a new process for allowing students to short-cut the true learning process. The intent of these new goals is the qualitative understanding of content as well as the development of scientific thought within the student as a tool for the student to think for his or her own self.

McDermott (McDermott 1990) characterizes instructors as conscientious, committed, enthusiastic and knowledgeable stating strongly that in general Physics instructors correctly teach the content of Physics with acceptable accuracy and precision. Yet classroom instruction fails us because we tend to see our students as “younger versions of ourselves.” We tailor our instruction toward our positive academic experiences and what inspired us to be Physicists. Yet we tend to have a very specific mind set which may or may not coincide with our students. The actual instruction itself tends to be

> … Generalizations are often fully formulated when they are introduced and students are shown how to apply them to specific examples. Very little inductive thinking is involved; the reasoning is almost entirely deductive; the student is not actively engaged in the process of abstraction and generalization. (McDermott 1990)

Obviously this instruction would be well- suited if we were teaching ourselves, but on average, only a small minority in an introductory Physics course become engineers, Physicists, etc. McDermott(1990) characterizes successful instruction as student-oriented as well as student-active; Balanced between lecture, textbook, computer supported and open-ended discussion, demonstration, and lab discovery. The students should be supported in the obtaining of relevant information but also allowed to discover the essence of the content and its application,

> …All individuals must construct their own concepts…The student is not viewed as a passive recipient of knowledge but rather as an active participant in its creation.

Alternative Instruction

What is lacking? Obviously we model a process for students to follow, assign practice to help define that process and eventually test the finer points of the process to ascertain if our students can repeat it before us. But when does the student take the "reigns" of thought and pilot the course of their learning? Within this context, how are they any different than Pavlov's dog constantly salivating as we ring our bell? Did the dog really understand the intricacies of the finely cooked meal, or did he not just respond to being hungry? We all maintain a constant conversation within our heads relative to the stimulus we are experiencing. As I instruct my students, how do I know that they are correctly internalizing what I teach? Are they truly analyzing their preconceived perceptions in light of the new content I am presenting or are they just "hungry"? Are they truly evolving intellectually or are they just performing the tasks at hand to ease the "pain" of the moment?

Instructors must realize that our students are not just clones of our habits. We are only a tiny piece of their learning process. The student is an evolving entity developing as a product of their interaction with a vast array of chaotic, conflicting signals. Contemplating this continual stimuli causes a conversation within the mind of the child as they process information. If the instructor ignores this conversation the conceptual understanding will suffer in relation to the student's ability to induce and deduce information.

Many researchers conclude that alternative approaches instead of or in addition to lecture is warranted. Clement (Clement 1989) stated that preconceptions once "fixed" can become powerful allies to the instructor, and as "anchors" create a pathway for understanding just as it had been a blockade before. He advocates the use of many examples with the use of "bridging" an understood scenario by the student to a common misconception. Such as the case stated earlier where students struggled to grasp the "pushing" of a table on a cup, Clement (1987) suggested relating to a spring pushing on the same cup. In turn, this new understanding could then be used to explain the floor "pushing" against the sliding puck.

PEG developed an entire system of Physics by Inquiry (McDermott 1996) which uses a lab setting where students interact with simple demonstration of concepts to develop understanding by observation and modeling which is directly linked to real world phenomena. An important component of this method is conceptual questions which continually help the student access their thoughts in relation to the demonstration. This type of "remodeled" classroom was the focus of a study at Arizona State University and significant learning gains were seen between students in these classes and others placed in traditional, lecture style classes. (Falconer 2001)

Christine Chin studied the thought process of students to develop better forms of instruction by evolving teacher questioning in hope of opening this silent conversation within the students' minds so their perceptions can be addressed.

> Particular attention was paid to questioning exchanges that stimulated productive thinking in students, as manifested by their verbal responses. A framework was developed that included four questioning approaches adopted by the teachers. This included Socratic questioning, verbal jigsaw, semantic tapestry, and framing. This paper describes these various questioning approaches, their features, and the conditions under which they were used. It also discusses the implications of these approaches for instructional practice. The findings from this study have potential in translating research insights into practical advice for teachers regarding tactical moves in classroom discourse, and provide guidelines for teachers to increase their repertoire of questioning skills. (Chin 2007)

The days that employed the “one man show” approach, lifting the professor to star status, relegating the students to little more than innocent by-standers within the audience are losing credibility in light of this research and others Boller (1999), Rogers (2007), Williams(2007). Education is a participation event; the students should be playing the game. It is a student-centered activity. Research shows Interactive Instruction experiences the greatest gains and most would agree that it is the thought process within the student that must be addressed, this silent conversation debating the content of our instruction.

Peer Instruction by Mazur

> One problem with conventional teaching lies in the presentation of the material. Frequently, it comes straight out of textbooks and/or lecture notes, giving students little incentive to attend class" (mentally or physically). "That the traditional presentation is nearly always delivered as a monologue in front of a passive audience compounds the problem. Only exceptional lecturers are capable of holding students' attention for an entire lecture period. It is even more difficult to provide adequate opportunity for students to critically think through the arguments being developed. Consequently, lectures simply reinforce students' feelings that the most important step in mastering the material is memorizing a zoo of apparently unrelated examples. (Mazur 1997)

After teaching a subject basically twenty years, one gains an appreciation for the simple explanation of why our greatest efforts may not create much gain in the thought process of our students. For the first half of my professional career I would have contended the more I did, the more my students would succeed. The better I expressed the material, the greater comprehension attained by my audience. As I was performing my "song and dance," if I sang on key and maintained a perfect rhythm, of course my charges would not only be entertained, but learn in the process. As many instructors eventually realize, the best I would attain under that system were clones who could only repeat what I did, devoid of much understanding. A perfect example of this was the frustration both my students and I felt with the concept of acceleration. They could quote the definition, state its limits and successfully complete practice problems using the formula, but in continued application to new situations they displayed a lack of actual comprehension. In hindsight, I understand their struggle as I remember the evolution I have experienced in 30 years of trying to personally grasp and teach this subject. When I read Peer Instruction, I saw a parallel to my struggle and an instructional method I hoped could be a new tool for me to progress as an educator.

Research such as McDermott (1990), Falconer (2001) and Clement (1987) has proven that a student, if not mentally and physically engaged in the learning process, will show very few cognitive gains. Not only is the acquisition of new information important, but is it vital that this new information is applied to old beliefs as they are aggressively reevaluated (J Clement 1987).

> Finding 3. Many preconceptions are deep seated and resistant to change…
>
> Implication 3. The fact that some preconceptions resist change in the face of traditional lecture-demonstration based teaching means that more powerful teaching techniques will have to be devised. Apparently the direct transmission model of direct verbal input from lectures or text to students who are "empty vessels" is not adequate in these cases.

Mazur developed Peer Instruction as an alternative teaching process that marries the act of lecture with the hands-on application specifically directed at the revaluation of preconceived conceptual beliefs in light of new knowledge. In theory it is a strong model to help students fine-tune their thought process, eradicate erroneous ideas and fortify a basal understanding of Physics concepts.

> …an effective method that teaches the conceptual underpinnings in introductory Physics and leads to better student performance on conventional problems. Interestingly, I have found this new approach also makes teaching easier and more rewarding. (Mazur 1997 p. 10)

It was my intent to study the value of the response component of Peer Instruction within the high school setting as a means of stronger conceptual understanding of Physics concepts within my regular Physics classes; to ascertain its ability to remove erroneous preconceived ideas in the light of new information, and to assist my students in streamlining their analytical thought process skills. Yet the overriding goal that I am trying to ascertain is my ability to incorporate the response component of this particular method and whether I see the same gains Mazur claimed in his book.

Applying Peer Instruction

Peer Instruction does not remove the class lecture component of instruction, so the student is expected to read material outside of class to gain background of the material. In class, after Mazur highlights key points of the content, "conceptests" follow to test the conceptual understanding by the student.

Each conceptest has the following general format:

1. Question posed	1min
2. Students given time to think	1min
3. Students record individual answers (optional)	
4. Students convince their neighbors (peer instruction)	1-2 min
5. Students record revised answers (optional)	
6. Feedback to teacher: Tally of answers	
7. Explanation of correct answers	2 min

"…The students are first given time to formulate answers and then asked to discuss their answers with each other. This process (a) forces the student to think through the arguments being developed, and (b) provides them (as well as the teacher) with a way to assess their understanding of the concept. (p. 10)

Methodology

I used my four regular Physics classes to populate a control and experimental groupings. I grouped my 1st and 6th hours together as a base group (43 students) and my 4th and 5th hours as an experimental group (42 students) to remove any direct affect from "morning/ afternoon" classes. To the best of my knowledge, these students were randomly assigned to my classes by our guidance office. For the first portion of the school year I taught both groups as identically as possible through base subjects such as the scientific method, metric system, dimensional analysis, graph analysis, velocity, acceleration, vectors, kinematics equations, etc. I acclimated my students to pre/post testing during this period.

The Force Concept Inventory was used by Mazur to test his student's conceptual understanding of forces. Even though there have been some questions to what it truly tests (Huffman 1995) most research shows a greater acceptance and an overwhelming reliance on it as a proven determinate of force concept understanding. (Hestenes 1998)

> The Force Concept Inventory (FCI) is currently the most widely used assessment instrument of student understanding of mechanics.[1] This 30-item multiple-choice test has been very valuable to the physics education community by helping to show that students can solve common types of quantitative problems without a basic understanding of the concepts that are involved. 2 Since the test is so easy and quick to administer, many physics instructors have given it to their classes and have been surprised by the low scores of their students. This has, in part, helped to fuel the growing interest in physics education research. (Henderson 2002)

As I began the unit on forces, I first pre-tested both groupings using the FCI to determine a base line level of their conceptual understanding of force. My control group had an average raw score of

6.3 ± 1.0 on the pretest where the experimental group had an average score of 6.5 ± 1.0. The overlapping of these two means, showing them to be statistically the same number, leads me to assume the pre-instructional understanding of force concepts by each group was the same. (See figure 1)

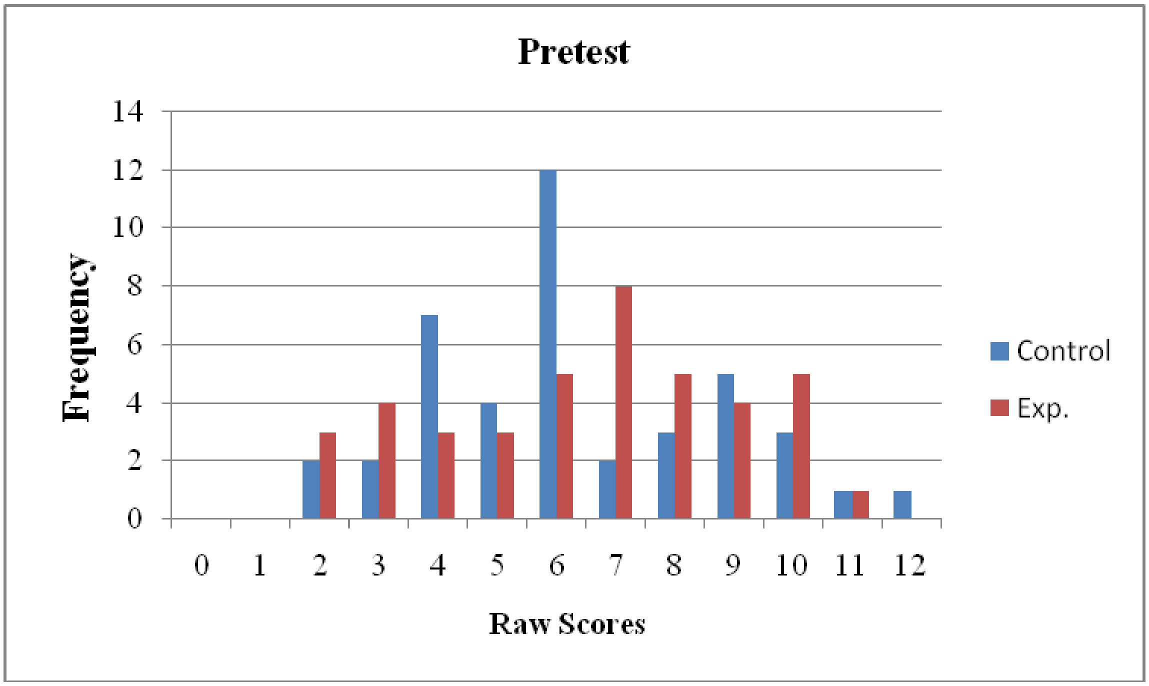

Figure 1. A comparison of FCI pretest raw scores, Control v. Experimental, depicting the two groupings as comparable in pre-instruction level of force concepts. Note that the distribution of each is fairly similar.

During the next 5 weeks I taught the complete unit on forces, again as identical as possible, adding in the conceptests from Peer Instruction curriculum. All classes would read the question and have a minute or so to contemplate an answer. All classes would attempt to answer the question. My control group would simply voice their opinion by stating the answer outloud or by raising hands. My experimental group used index cards to display their votes and it was understood that the discussion would not move forward until everyone voted. At this point, I would allow individuals to support their vote by discussion within small groups or to the entire class. All experimental students would vote again and adjustments would be noted. I would then discuss all answers, right or wrong, with the class to express a more complete picture of the concept.

The following is an example of a conceptest I used to focus on acceleration's dependence on force and changing velocity as a vector quantity.

> A car rounds a curve while maintaining a constant speed. Is there a net force on the car as it rounds the curve?
>
> 1. No—its speed is constant.
>
> 2. Yes.
>
> 3. It depends on the sharpness of the curve and the speed of the car. (Mazur 1997)

During the instruction of the force unit, over about four weeks, I did not directly teach any items on the test. At the end of the unit I gave the FCI as a post test. I found the average raw gain of correct answers for my control group to be 2.6 with a standard deviation of 3.5. Statistically, it is possible that this number is zero hinting that these students on the average had no gain. The experimental group showed at least a slight increase with an average raw gain of 3.1 with a standard deviation of 2.7. When the histograms of each are compared, they show similar distributions and the experimental group seems to have a slightly larger gain. But the comparison is inconclusive. (see Figure 2)

Because the pretest scores are a large proportion of the total score (28), I used normalized gain ("fraction of the available improvement that is obtained" (Stewart 2007)) instead; The normalized gain for the control group was 0.11 ± 0.16. When each student's gain is plotted against their pretest

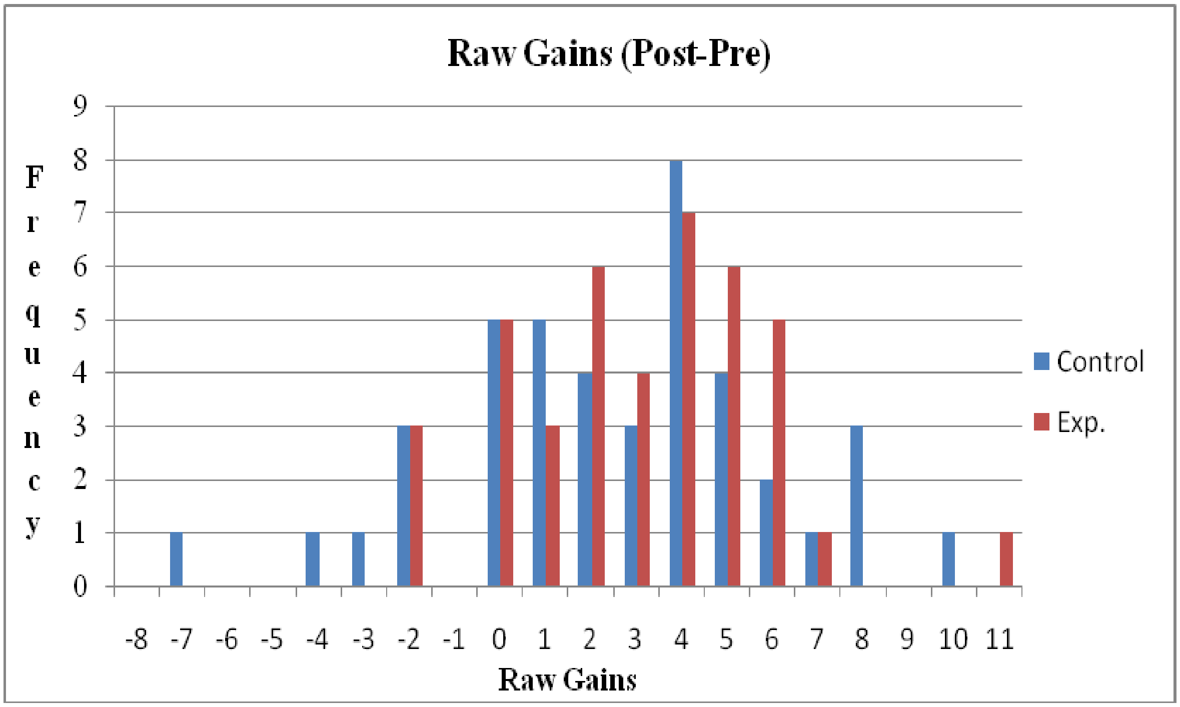

Figure 2. Raw gains, Control v. Experimental, of the difference between FCI posttest sores and pretest scores.

score again I see more students with positive gain than no or negative gain (see Figure 3). But the deviation around the mean shows that it cannot be assumed that the value is greater than zero.

The experimental group's normalized gain was 0.14 ± 0.12. Statistically again this does hint at a slight gain above zero. When their normalized gain was plotted against their pretest, it shows more data points above zero than at or below (see figure 4)

A statistical comparison of the deviation around these means, control being 0.11 ± 0.03 with an n = 43 and experimental being 0.14 ± 0.02 with an n = 42, cannot conclude that they are different numbers. A p-test shows that there is a 21.5 % probability that the difference is a random occurrence.

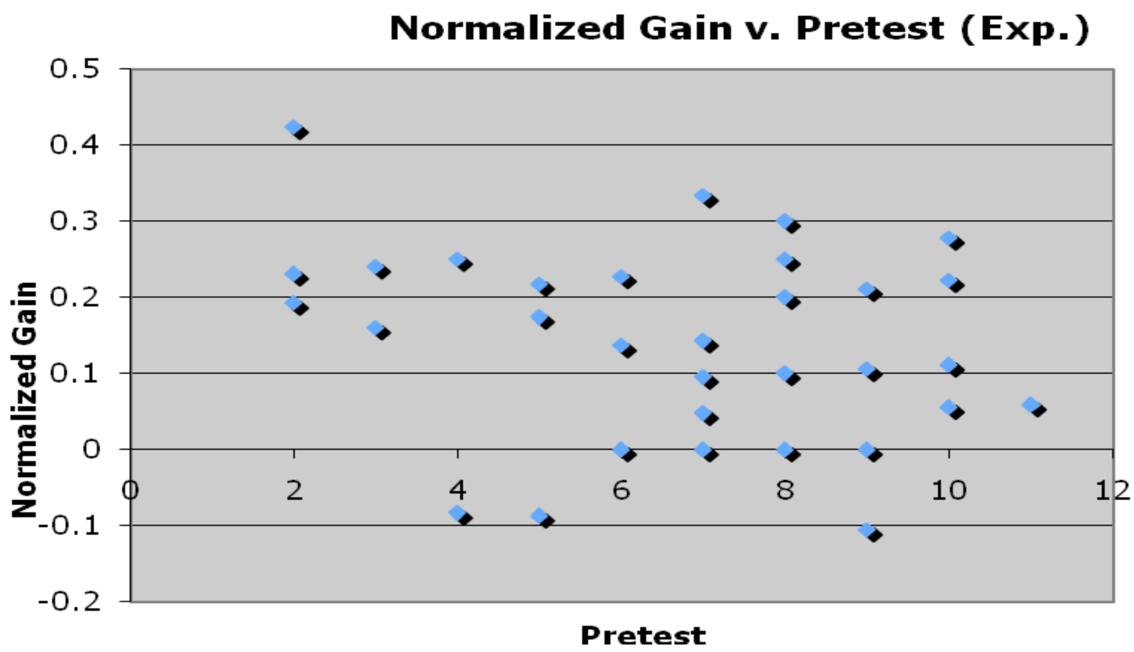

Figure 3. Control Normalized Gains of Post/Pre-Test scores plotted against Pre-test scores.

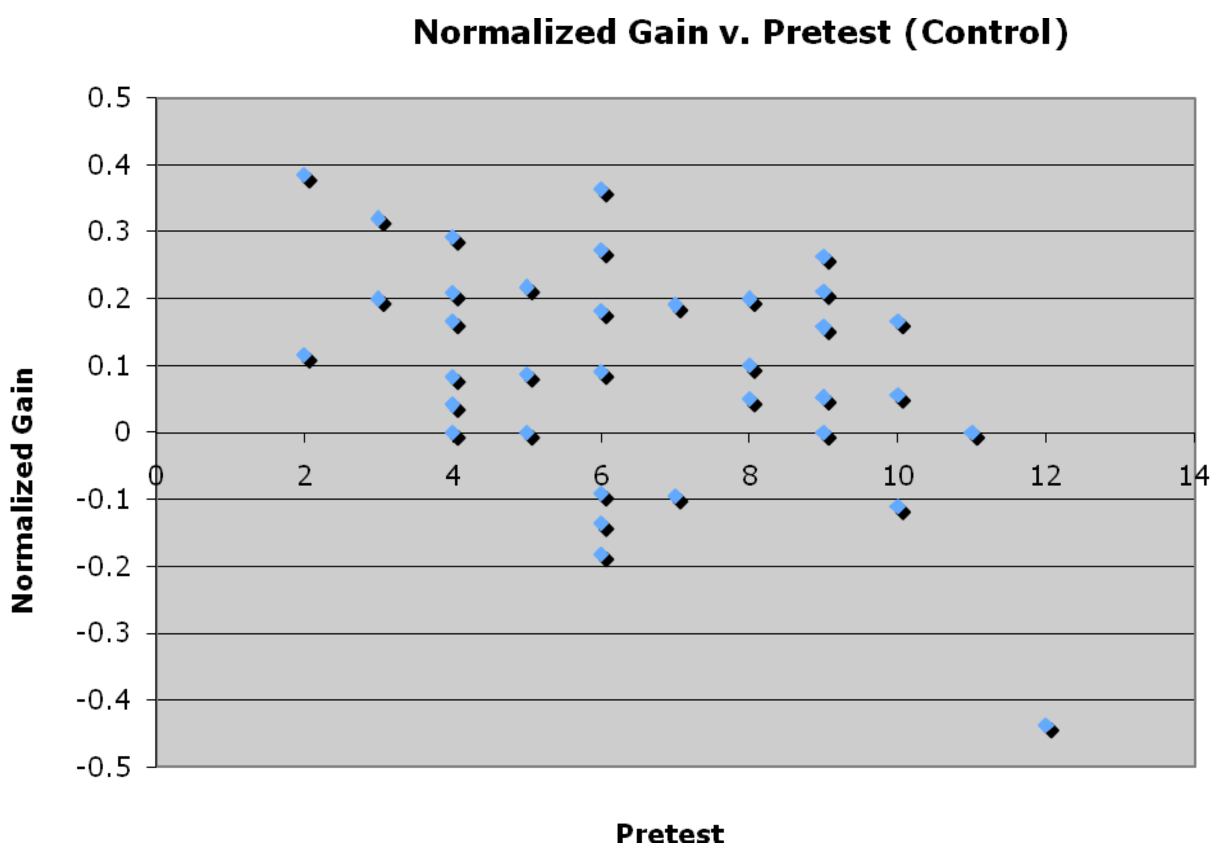

Figure 4. Experimental Normalized Gains of Post/Pre-Test scores plotted against Pre-test scores.

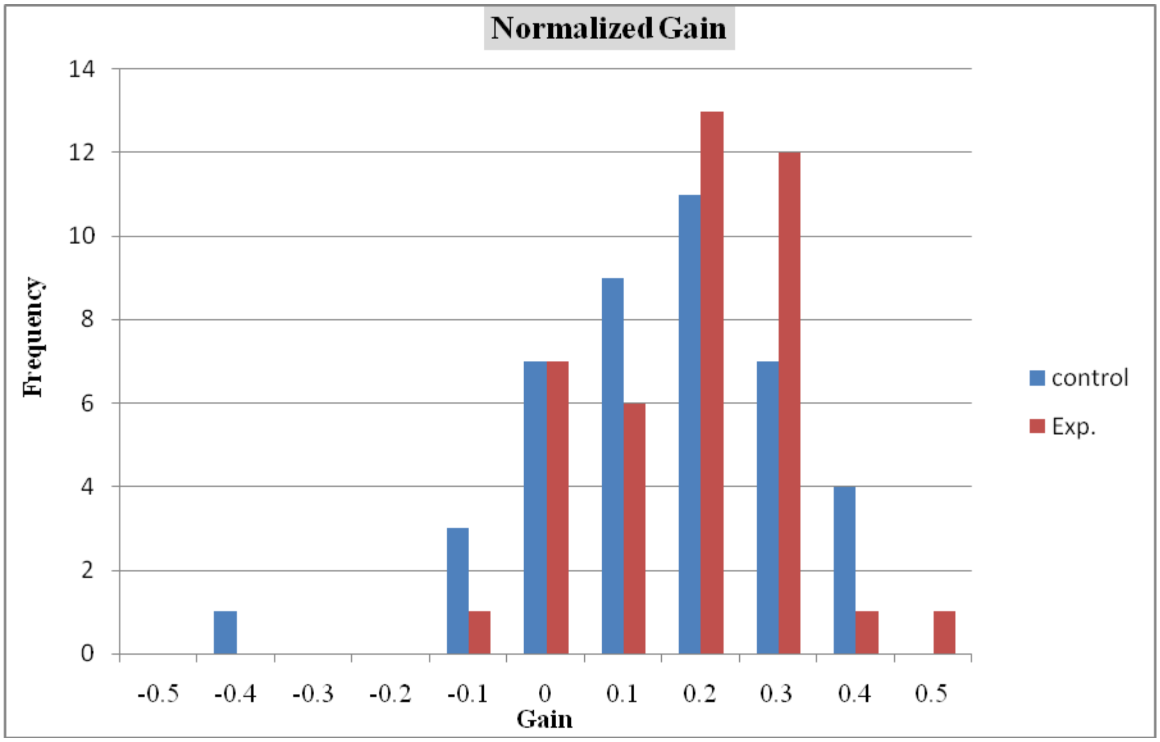

Figure 5. Normalized Gain, Control v. Experiemental, of the difference between FCI posttest sores and pretest scores (using an n value of 43 for Control and an n value of 42 for Experimental.)

Table 1. Summation of FCI Data.

	Control	**Experimental**
Pretest Mean	**6.3 ± 1.0**	**6.5 ± 1.0**
Post Test Mean	**8.9 ± 3.2**	**9.6 ± 2.9**
Mean of Raw Gain	**2.6 ± 3.5**	**3.1 ± 2.7**
Normalized gain	**0.11 ± 0.16**	**0.14 ± 0.12**
Std. Dev. of mean	**0.11 ± 0.03**	**0.14 ± 0.02**

P(T<=t) one tailed = 0.215

Statistically Speaking

Comparing the mean score for each grouping (control vs. experimental) using a single-tailed t-test, the result shows a 21.5 % probability that the increased normalized gain of the experimental group to be nothing more than a random occurrence. Given the fact that this result does not even display a 90% confidence level, this result is inconclusive about the impact of the response component of Peer Instruction of student performance on the FCI. Given that my n value was rather small (less than 100 students) as well as the many variabilities and limitations inherent in a normal public high school, my results would have to be viewed as inconclusive. Obviously any future study would have to enhance both groups by at least a factor of 10 before a statistically significant conclusion would likely be reached. Yet I do see fewer students in the experimental group (3 of 42) having negative gain in comparison to the control (7 of 43). Also there is a hint of stronger gains in experimental students (**3.1 ± 2.7)** as compared to the control students (**2.6 ± 3.5)**.

That being said I must extend this opinion beyond the numbers. The motivation for this project had as much or more to do with the open dialogue and communication created by this system between the student and myself and even more so within the student.

One of the first observations I made was in my 5th hour class. A rather quiet, disconnected group where much of the discussion involved me posing a random question and, out of a class of eighteen students, one of only three (typically the same guy)would express a short one to three word answer as everyone else gazed expectantly at me to move on. Academically over-all they were not a low performing group. Though through random discussions, I would surmise their area of choice to be more the humanities classes (in short, they were not strong science students especially in the applied sciences). Yet when they were required to openly make a choice in relation to the concept-test of Peer Instruction, they opened up to communicate the conversation hidden within the recesses of their own thoughts. This method pushed them to analyze their own beliefs in relation to the content being discussed, to formulate some cognitive thought to support their answer. I established early in the process that I would randomly have them justify why they made a certain choice. I would balance this scrutiny by forcing the conversation away from the focus of the "right answer" and toward the inner workings of the problem. The answers were only used as reference to the endpoint of the problem and a student could learn from the right and the wrong answers.

One of the main points of emphasis of Peer Instruction, is the fact that the student has to respond. They cannot hide. They must display their thought process on that index card. Once this was accomplished, it seemed to open a dialogue where the student would feel justified to continue the discussion. It seemed that since other students chose the same wrong answer it was ok to talk about why. What seemed to bother students more than being wrong was being isolated. If the discussion showed a consistency of misunderstanding, then the students seemed motivated to correct the misconception. In the future, I will pursue techniques that focus on these dynamics.

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Vita

Wiley Daniel Iverstine was born to John and Joan Iverstine in Baton Rouge, Louisiana, in September, 1965. He graduated from Loranger High School in May 1983. The following August, he entered Pearl River Coast Community College on athletic scholarship. In May 1990 he graduated cum laude with a 3.5 from Southeastern Louisiana University with a Bachelor of Science degree in chemistry education. He entered Louisiana State University Graduate School in June 2008 and is a candidate for the Master of Natural Sciences degree. He currently teaches Physics (AP & Reg.) and Chemistry (H) at Central High School as well as regular, organic and water chemistry at ITI Technical College. He also co-coaches the Robotics Team at central high.