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Implementing *Peer Instruction* in Cegep
(L'enseignement par les pairs au cégep)

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Abstract

The current study looks at the implementation of the Harvard *Peer Instruction* (PI) method in Cegep. *PI* is an instructional approach which places a great emphasis on basic concepts. After a brief lecture, students are presented in class with ConcepTests: multiple-choice conceptual questions. Students choose their answer by raising a flashcard displaying the number of their choice to the instructor or by entering their response on wireless handheld devices colloquially called ‘clickers’. Instructors can then assess in real time what proportion of students correctly answered the question and what the distribution of misconceptions is. Instructors then ask students to turn to their closest neighbour and convince them of their answer. Two to three minutes of peer discussion ensue. After this discussion students re-vote (using flashcards or clickers) and the instructor carefully explains all remaining misconceptions.

Objectives

The current study has three main objectives. The first is to determine whether *PI* can be implemented in Cegep. The second objective is to determine whether *PI* is more effective than traditional instruction in Cegep. The final objective is to establish whether the technology (clickers) used in *PI* adds significantly to students’ conceptual learning.

Methodology

A first person narrative account, inspired by case-study methodology, presents an implementation of *PI* in Cegep and describes its feasibility.

A quasi-experimental design using two PI treatment groups and one traditional didactic instruction control group was used to establish the effectiveness of PI and the difference made by using clickers. Both treatment groups used PI but differed in the way students reported their answers: one group used flashcards whereas the other used clickers. Both PI groups were taught by the primary investigator. The instructor for the control group was matched to the PI instructor by gender, age and teaching experience. Differences in conceptual learning gains were assessed with the Force Concept Inventory (FCI) and concept confidence levels. Traditional problem solving skills were assessed through the department’s common final exam. To determine the added effectiveness of clickers, the flashcard group was compared to the clicker group. The effectiveness of PI relative to traditional instruction was established by pooling both PI groups and comparing them to the traditional instruction control group.

Results

Main findings include the real feasibility of implementing PI in Cegep. PI was warmly welcomed by administrators, teaching colleagues and students alike. It requires little changes that nevertheless have profound impacts on the way instruction is approached. PI was also found to enable significantly more conceptual learning ($p=0.008$) than the traditional approach. Furthermore, although less time is spent on traditional problems, PI students’ problem solving skills did not differ from the control group. Finally, the use of clickers in PI did not procure any significant learning advantage. Therefore, PI is an effective approach regardless of the means used to report answers. In other words, the technology is not the pedagogy.

Résumé

Cette étude analyse la mise en œuvre de l’approche ‘Peer Instruction’, ou d’apprentissage par les pairs (AplP) développée à Harvard par Eric Mazur. L’AplP est une méthode qui place une emphase particulière sur les concepts de base. Après un bref exposé magistral, les élèves sont présentés avec un ConcepTest : une question conceptuelle à choix multiples. Ils choisissent alors une réponse soit en appuyant le numéro du choix sur une télécommande ou en montrant le numéro choisi sur un carton. L’enseignant est alors en mesure de déterminer en temps réel la proportion d’élèves qui comprend le concept ainsi que la distribution des mauvaises conceptions. L’élève doit ensuite se tourner et convaincre un(e) autre élève de sa réponse. Après cette discussion, les élèves entrent encore un choix de réponse (avec carton ou télécommande) et l’enseignant explique pourquoi les mauvaises conceptions restantes ne sont pas correctes.

Objectifs

Cette étude comporte trois objectifs. Le premier est de déterminer si l’AplP peut être implémenté au Cégep. Le deuxième objectif est de déterminer si l’AplP est une approche plus efficace que l’enseignement traditionnel au Cégep. L’objectif final est d’établir si la technologie des télécommandes ajoute de façon significative à l’apprentissage.

Méthodologie

Pour déterminer si la méthode est implémentable au Cégep, une description narrative de l’approche, telle qu’implémentée au Cégep John Abbott, est présentée. La réception de l’approche de la part de l’administration, des collègues ainsi que des élèves y est décrite. Sont aussi décrits les modifications requises aux structures de cours, certains problèmes encourus ainsi qu’une liste de recommandations pour pouvoir les éviter.

Un schéma d’étude quasi-expérimental ayant 2 groupes d’AplP et un groupe témoin (enseignement didactique traditionnel) est utilisé pour déterminer l’efficacité de l’AplP au Cégep. Les deux groupes d’AplP étant enseignés par le chercheur principal, diffèrent cependant de par la méthode utilisée pour répondre au questions (cartons vs télécommandes). L’enseignant du groupe témoin a été jumelé à l’enseignant d’AplP de par leur age (+/- 3 ans), sexe (M) et expérience d’enseignement (+/- 1an). Les différences en gains conceptuels sont établies à l’aide du FCI et de niveaux de confiance. L’aptitude à la résolution traditionnelle de problèmes est mesurée par la note à l’examen final commun du département de physique. Pour déterminer si les télécommandes ajoutent à l’apprentissage, le groupe ‘carton’ est comparé au groupe ‘télécommandes’. Pour déterminer si l’AplP est plus efficace que l’enseignement traditionnel, les deux groupes d’AplP sont confondus et comparés au groupe témoin.

Résultats

Les résultats principaux incluent la faisabilité de l’AplP au Cegep. L’approche fut bien reçue par l’administration, les collègues ainsi que les élèves. La méthode requiert peu de changements qui néanmoins ont des effets profonds sur la façon dont l’enseignement est approché. L’AplP est une méthode qui permet significativement ($p=0.008$) plus d’apprentissage conceptuel. De plus, même si moins de temps a été alloué à la résolution de problèmes traditionnels, les élèves d’AplP ne diffèrent pas en aptitude de résolution de problèmes par rapport aux élèves du groupe témoin. Finalement, les télécommandes ne procurent pas d’avantage significatif d’apprentissage. L’efficacité de l’AplP est donc indépendante de la technologie car la technologie est distincte de la pédagogie.

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Chapter 1

Clickers in the classroom: Using the Harvard *Peer Instruction* model in Cegep

Introduction

The way science is taught today in most college classrooms does not differ significantly from the way it was taught 100 years ago (Beichner *et al.*, 1999). However, much has changed since. First, students have changed. Today a majority of science students are females (MEQ, 2004), and most science graduates will opt for careers in applied science as opposed to pure sciences. Second, our understanding of how people learn has changed (see for eg. Bransford, Brown, Cocking, 2000). For instance, the perception that students arrive as blank slates (*tabula rasa*), held since the time of Aristotle, is no longer acceptable and is better replaced by a constructivist view whereby learners construct new understanding from previous knowledge (Cobb, 1994; Piaget, 1973, 1977, 1978; Vygotsky, 1962, 1978). Third, society and educators' expectations from students have also changed. As best put by Nobel laureate H. Simon (1996) "*the meaning of* "knowing*" has shifted from being able to remember to being able to find and use*". Thus, literacy is no longer seen as the ability to read and write in order to fill job applications but rather to understand the essence of a text and make out its meaning. Students are now expected to emerge as educated citizens. Finally, the effect of information technologies has completely changed the way we communicate and approach information. Yet, although the student population, the expected learning outcomes and the technologies have significantly changed in the course of a century, most science classrooms ignore these changes and present learners with abstract tasks that have no inherent meaning to them (Klausmeier, 1985) making construction of meaning questionable at best. Thus, although much has changed in a century, many science instructors resort to teaching the way they were taught (Felder, 1993), that is, not much differently from the way science was taught 100 years ago.

In an attempt to address this concern, an information technology driven instructional approach called *Peer Instruction* (Crouch & Mazur, 2001; Mazur, 1997) was developed at Harvard by physicist Eric Mazur. In *Peer Instruction*, students use wireless handheld devices, colloquially called 'clickers', to provide real-time feedback to the instructor. This method has been warmly welcomed by the science community and adopted by a large number of American colleges and universities[1], due among other reasons to its common sense approach and its documented effectiveness (Fagen *et al*, 2002; Crouch & Mazur, 2001, Mazur, 1997). Although, this method has been effectively used for 15 years, this is the first study documenting its applicability and effectiveness in Quebec Cegep institutions[2].

What is Peer Instruction?

Brief History

As recounted in his book on *Peer Instruction*, Eric Mazur (1997) developed the approach when, having taught for a few years, he became aware of a non-numerical, conceptual inventory of introductory physics concepts called the Force Concept Inventory (Halloun *et al.,*1995; Hestenes, Wells & Swackhamer, 1992; Halloun & Hestenes, 1985). The authors of the FCI devised the test to quantitatively gauge the extent of students' preconceived –often "Aristotelian" (DiSessa, 1982)- views of the world, despite formal physics training. The FCI, a multiple choice instrument, is unique in that it asks in simple terms conceptual physics questions and proposes distractors[3] that are compiled from the most prevalent misconceptions given by students in interviews (Halloun & Hestenes, 1985a,b). Thus, to answer FCI questions, students do not resort to computations or memorized algorithms but have to identify the accurate concept from a number of "d*istractors*". For instance, one FCI question asks:

[1] Fagen *et al* (2002) reports survey data of 384 instructors –outside of Harvard- having used Peer Instruction. Note that of these only 6% were 2-year colleges that would bear some resemblance to Cegeps.
[2] Searches of ERIC and Google Scholar yield not entries for 'Peer Instruction' and 'Quebec' or 'cegep'
[3] "Distractors" are defined and incorrect choices of the FCI which were compiled from most prevalent wrong answers given by students in interviews (Halloun & Hestenes, 1985a).

A large truck collides head-on with a small compact car. During the collision:

a) *The truck exerts a greater amount of force on the car than the car exerts on the truck.*
b) *The car exerts a greater amount of force on the truck than the truck exerts on the car.*
c) *Neither exerts a force on the other, the car gets smashed simply because it gets in the way*
d) *The truck exerts a force on the car but the car does not exert a force on the truck.*
e) *the truck exerts the same amount of force on the car as the car exerts on the truck.* Halloun *et al. (1995)*

Frequently students will opt for the erroneous choice a) since the truck, being larger, must "carry more force". However, forces occur in action-reaction pairs that are identical in magnitude but opposed in direction (Newton's 3rd law). Therefore, the force that the car exerts on the truck must be identical in magnitude to the force the truck exerts on the car (correct answer e). The counter-intuitive nature of this statement resides partly in the fact that the car driver will sustains more injuries than the truck driver. However, this is not due to a greater force acting on the car. In fact, a force identical in magnitude to that acting on the truck yields a greater car deceleration since the car has a smaller mass, explaining why the car driver feels a greater impact. In putting forward these misconceptions, the FCI reemphasizes that physics is often counter-intuitive and that students enter physics classrooms not as blank slates but rather with many pre-conceptions. To experts, the correct answers to these questions are straightforward, at times bordering triviality.

Mazur decided to give the test to his students and the end of the semester. He presented it to students and downplayed its importance, worried that students would scoff at such a basic test. After all, these were Harvard students that had very successfully passed physics in high school (and on the SATs). Yet, his students were uneasy with the test as best exemplified by one who asked:

> "*Professor Mazur, how should I answer these questions? According to what* **you taught us** *or according to the way* **I think** *about these things?*" (Mazur, 1997)

In fact, Mazur's students did not perform as he had expected. To his great surprise, not only did students not grasp the fundamental concepts after 1 or 2 years of seemingly successful high school physics training (which after all got them into Harvard…) but a large number of misconceptions remained even after a semester of *his* instruction! Mazur's students had always positively evaluated his teaching, and their performances on exams were quite good. Yet, even some of the high performing students did not fully grasp the basic concepts (Mazur, 1997). In fact, this turns out to be one of the most revealing finding of large scale FCI data studies. Indeed, a meta-analysis of more than 6500 respondents (Hake, 1998) has shown that a semester of traditional instruction changes only marginally students' conceptual understanding[4] of physics. Furthermore, this gap between what instructors think their students understand and what the FCI shows has made the FCI "*the most widely used and thoroughly tested assessment instrument*" in physics (McDermott & Redish, 1999) and has rendered the FCI into the central role in driving the physics reform efforts of the past decade (Crouch *et al,* 2001).

Development of the Method

Although Mazur's students were quite proficient in traditional problem solving, he decided to explicitly address his students misunderstanding of basic concepts. This required making some modifications to the instruction format. Mazur decided to present students with a brief lecture (7-10 minutes, within limits of average adult attention span), the content of these lectures being similar to traditional curriculum differing only by an increased emphasis on non-algorithmic concepts. After the brief lecture, students were presented with a *ConcepTest*: a multiple choice conceptual question having misconceptions available as possible answers. To gauge what all students were thinking, each student was given five flashcards each with a letter (A,B,C,D,E) corresponding to the five available choice of answers. When presented with a ConcepTest, students would raise the flashcard corresponding to their preferred choice.

[4] Data suggests that traditional instruction yields "normalized gains" <g> of approx 20%. This implies that 80% of missing basic concepts on entry are still not acquired after a semester of traditional instruction.

Note that <g> is defined as: <g> = (Post-test score% - Pre-test score%)/(100%- Pre-test score%)
Which is the ratio of the actual gain (<%post> - <%pre>) by the maximum possible gain (100% - <%pre>).

Figure 1.1 Students involved in *Peer Instruction* using Flashcards.
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This provided the instructor with real-time feedback of the approximate proportion of correct answers as well as the distribution of misconceptions. A few years later, Mazur replaced flashcards with "clickers", that is, one-way infra-red wireless keypad devices which bear resemblance to TV remote controls.

Figure 1.2 An infrared 'clicker'

To state their choice of answer when presented with a conceptual question, students simply press the corresponding choice number on the clicker and the data is transmitted to a receiver connected to a computer, usually located at the front of the classroom. The instructor then has *instant feedback* on how the students in his classroom have grasped the concept by assessing in real time the exact percentage of the class having the correct answer as well as the percentage of students holding each misconception.

As instructors, we often believe that our students have understood a concept (from the questions asked, the non-verbal cues, etc.) when in fact many misconceptions may still persist. *Peer Instruction* allows instructors to assess student comprehension in real time and thus determine whether one can proceed to build on newly acquired knowledge or if more time is required to consolidate the knowledge.

Using clickers in *Peer Instruction* may also provide additional advantages such as the following four. First, the exact distribution of answers can be obtained at a glance. Indeed, clicker software yields a histogram with exact percentage values for each answer, relieving the need to count or '*guestimate*' the number of raised flashcards. Second, clickers allow students to participate anonymously since only conglomerated data is included in the histogram. Thus, students need not feel that they will look silly in the eyes of their instructor or peers by choosing some answer, and can therefore participate fully and freely. Third, clickers allow students to enter their level of ***confidence*** -High, Medium, Low- for each selected answer. This allows instructors to gauge not only the conceptual change in their students by the evolution of their students' confidence with respect to different concepts. Finally, students are engaged in what seems to be an academic emulation of the TV show: "*who wants to be a millionaire*" and some instructors have reported increased attendance with the use of clickers.

Using Peer Instruction: An implementation algorithm

Peer Instruction is a student-centered approach which is highly interactive. In any given *Peer Instruction* class, the next instructional step depends on students responses, as content delivery is tailored to student understanding. The general procedure begins with a brief lecture (≈10min) and is followed by a ConcepTest. What happens next in class depends on student feedback. An implementation algorithm is presented below.

If the concept is poorly understood (< 35% of correct answers), the instructor will revisit the concept and explain further before resubmitting the ConcepTest to the group. However, if the correct response rate is very high (>85%), most students have well understood the concept, and the instructor may simply address the remaining misconceptions that 15% of the class believes. Most frequently, the rates of correct response are neither very high nor very low. When moderate response rates (35%-85%) are obtained, students are asked to turn to their neighbour and try to convince them of their choice. This leads to 2-3min of discussion between students: the *Peer Instruction per se*.

Fig 1.3 Students involved in a *Peer Instruction* discussion.

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This discussion forces students to formulate their thoughts clearly and better represent the concept. Furthermore, a discussion of concepts between students withdraws the authoritative nature that a discussion with an expert instructor can have. Indeed, students may take an instructors' explanation as an authoritative fact and not pursue a line of reasoning as elaborate as would be done with a peer. Beyond having a more evenly balanced debate of conceptions, students also discuss from perspectives that are often foreign to the expert-instructor. Thus, students may be better equipped than instructors at understanding their peers' misconceptions and conceptual change may thus be facilitated. After discussion, students are presented with the same ConcepTest and are asked to revote. The instructor then acknowledges the correct response and explains why the remaining misconceptions are wrong. The method can thus be schematized as follows:

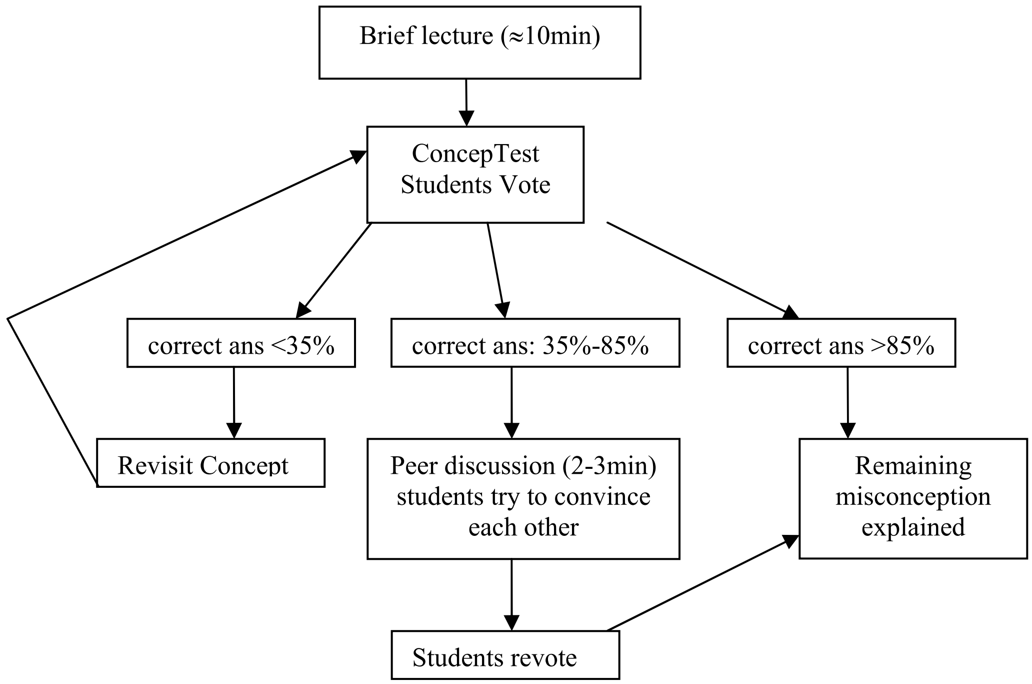


Figure 1.4 *Peer Instruction* Algorithm

Replicated findings show not only that after the discussion between peers, rates of right answers increase significantly[5] but that the acknowledged levels of confidence for the correct answer also increase (Fagen *et al*, 2002; Crouch & Mazur, 2001; Mazur, 1997).

Purpose of the study

The purpose of this study is threefold. The first is to determine whether the Harvard *Peer Instruction* approach can be implemented in Cegep contexts. Indeed, since *Peer Instruction* was initially developed in an elitist institution and later used mostly in American colleges and universities it is unclear whether the approach would be suitable to a public Cegep instruction where students are somewhat younger and range widely in aptitudes. Documenting inevitable first time pitfalls should assist interested instructors in avoiding foreseeable difficulties. To this effect, I will present a first person narrative account of my implementation of *Peer Instruction* at John Abbott college.

[5] Harvard, 10-year data shows rates of wrong-to-right answers of 32% compared to right-to-wrong rates of 6%, with overall 72% correct answers on the second vote and significant confidence level increases (Crouch & Mazur, 2001).
Data of a large number (384) of non-Harvard users (Fagen *et al*,2002) indicates that moderate conceptual knowledge gains (normalized gain = 0.39) occur significantly with Peer Instruction.

The second purpose of the study is to determine whether the use of *Peer Instruction* is ***effective*** in a public Cegep context. Indeed, although the method may be easily implemented, it remains to be shown whether its use offers a teaching and/or learning advantage over traditional instruction. That is, does *Peer Instruction* make teaching more effective, and if so how? and, does *Peer Instruction* significantly and sizeably enhance conceptual learning?

The final purpose of this study is to isolate the specific contribution of technology in learning. Initially, the *Peer Instruction* approach required students to use flashcards to communicate their answer to the instructor. Later the communication medium was changed to handheld clickers. The question remains whether the technological difference provides a teaching and/or learning advantage.

Chapter 2

Study Description and Methods

To determine whether *Peer Instruction* can be used in Cegep, qualitative and quantitative data were collected and analyzed in response to this study's empirical research questions. These questions were chosen first for their interest to Cegep faculty members and second for possible innovative contributions to a growing body of research in physics education. For instance, what is required from teachers to implement this innovative instructional approach? A first person narrative account of the pleasant and unpleasant surprises encountered when implementing the approach will be presented. This should enable interested teachers to minimize potential problems.

This study however, features a design which contributes uniquely to the field by addressing the specific effect of the technology in teaching and learning. Specifically, does the use of wireless clickers make *Peer Instruction* more effective than with flashcards? To date, although there have been numerous reports on *Peer Instruction,* none have studied the difference in effectiveness between using clickers and using flashcards. Furthermore, the study results should not only benefit to those interested in *Peer Instruction* but also those interested in finding specific contributions of technology in learning. A full description of the empirical research questions follows.

Empirical Research Questions

This study can be broken down into the following three empirical research questions.

1) Can the Harvard *Peer Instruction* approach be implemented in a Cegep context?
    a. Does the approach fit within institutional constraints?
    b. What modifications to course structures must be made?
    c. Are the required modifications easily feasible?

d. How is the approach received by other instructors?
e. How is the approach received by students?

2) Is *Peer Instruction* more effective than traditional didactic lecturing approaches?
   a. Does *Peer Instruction* ***increase*** conceptual change?
   b. Does *Peer Instruction* ***reduce*** traditional problem solving abilities?
   c. Does *Peer Instruction* work better for students of ***higher proficiency***?
   d. Does *Peer Instruction* ***increase*** students' confidence in concepts?

3) Is *Peer Instruction* with clickers more effective than with flashcards?
   a. Does the use of clickers ***increase*** conceptual change?
   b. Does using clickers affect students' traditional ***problem solving abilities***?
   c. Does the use of clickers ***increase*** students' confidence in concepts?

The answer to the first question and its subquestions are mostly qualitative, and will be presented in chapter 3. The answers to the second and third questions can be assessed quantitatively using different instruments described below. These quantitative results and analyses will be presented in chapter 4.

Study Description and Experimental Design

The first part of the study consists of a narrative description of the implementation of *Peer Instruction* in the physics NYA course at John Abbott College in the Fall of 2005. This narrative account, presented in the next chapter, portrays the different issues encountered from the project proposal stage to the actual in-class implementation of the approach. The second part of this study consists of testing the effectiveness of the approach in a public Cegep context where students range widely in abilities. The third part seeks the unique contribution of the technology in learning. The following quasi-experimental study design was used for the second and third parts of the study.

Three groups consisting of two *Peer Instruction* treatment conditions and one control section were studied. Of the two *Peer Instruction* groups, one used clickers while the other used flashcards to respond to in-class ConcepTests. Both *Peer Instruction* groups were taught by the primary investigator. The third group consisted of a control section where students were taught through traditional lecturing. The instructor for the control group was chosen as a match to the primary investigator by gender (male), age (+/-3yrs), teaching experience (+/- 1yr) and was anecdotally reported by students to be of similar teaching style. To isolate the contribution of the technology to the approach, the *Peer Instruction group* with clickers was compared to the *Peer Instruction group* with flashcards. To compare the effectiveness of *Peer Instruction with* respect to traditional didactic lecturing, both *Peer Instruction* groups were pooled and compared to the control section. All comparison measure are presented below in the '*Instruments*' section.

Instruments

Exam

Physics understanding is traditionally measured through procedural problem solving. In this study, these skills were assessed using the local physics department's comprehensive final examination. This exam was constructed by a committee of physics professors and had to be approved unanimously by all those teaching the course (10-12 instructors). Each instructor marked a single exam question for the entire cohort (not just for his or her students). This insured that no group had an exam of a differing difficulty, or a corrector of different generosity. Furthermore, the correctors of the exam questions were unaware of which students belonged to which treatment condition.

Conceptual Knowledge: FCI

In physics, students may know how to solve problems without having a complete conceptual understanding of the physics involved (Kim & Pak, 2002). Therefore, conceptual understanding was also measured the first and last week of the semester with the Force Concept Inventory (Halloun et al., 1995; Hestenes et al., 1992).

Analyzing raw FCI scores can be problematic. Indeed, pre-test scores are highly correlated to post-test scores which would be the case if no instruction were present. This tells us that post-test scores are in part due to how much conceptual knowledge the student came into the course with. This of course is unacceptable if one is trying to measure the specific contribution of an instructional method. If one wishes to know how much the students have gained from the instruction, the raw difference may be sought. However, the possible values for the difference between pre and post-test scores decrease as the pre-test scores increase (ceiling effect). Hake (1998) suggested using FCI scores as an intermediary to calculate ***normalized gains***. Normalized gains are defined as:

$$g = (\text{Post T} - \text{Pre T}) / (\text{max T} - \text{Pre T}) \qquad \text{Eq.1}$$

When the post-test score is greater or equal to the pre-test score, normalized gains yield a value between 0 and 1 representing the fraction of the concepts learned to the total concepts initially left to learn. For instance, a student scoring 40% before instruction has 60% of concepts left to learn. If she scores 70% after instruction, then she gained 30% of the total 60% possible left to gain, thus g=0.50. Among compelling arguments given for using normalized gains, is the reported fact that they are ***uncorrelated*** to pre-test scores (Hake, 1998, 2001, 2002) and therefore give a much better description of the conceptual gain due to instruction. In contrast, post-test scores are highly correlated with pre-test scores which would be expected if no instruction were present. We therefore intend to compare normalized gains across our treatment groups.

Non-cognitive measures: Confidence levels

New measures are presented and stem from the many concerns raised by the interpretation of FCI scores (Henderson, 2002; Steinberg & Sabella, 1997; Huffman & Heller, 1995). For instance, students may hesitate between two answers and guess the right one or the wrong one. They may be sure of a wrong answer and unsure of a right one or vice-versa. Furthermore, students conceptions seem not to fit in Boolean true-false categories (Bao & Redish, 2002), and a concept understood in one context is often misunderstood in other contexts (Huffman & Heller, 1995).

To address these issues, it may be interesting to assess students' confidence for each FCI item the way Mazur (1997) assesses confidence levels for in-class ConcepTests. This would allow us to infer how strongly a conception is held from the level of confidence expressed. Associating a level of confidence on a 5 point Likert scale (0= guessing; 1= not sure; 2= pretty sure; 3=confident; 4= Very confident) with each answer gives a better representation of students' conceptual state than the currently prevalent true-false view. The simple procedure of assessing confidences for FCI items yields 3 measures.

1) ***Average level of confidence***: represents the individual's overall confidence in answering conceptual physics questions. This level of confidence on the FCI before instruction can be compared to that found after instruction. This would allow us to determine the effect of treatment conditions (flashcards, clickers or control) on students' overall confidence regarding physics concepts. This could reveal interesting information particularly if an increase in confidence was to be found in some sections more than others. On the other hand, students may be less confident, which may occur if the new knowledge acquired is under construction and not fully "compiled" (Redish *et al.*, 2006). Note that pretest and postest average confidence levels can be also be used to compute a normalized average confidence gain. To find the normalized average confidence gain, the term T in equation 1 must simply be replaced by the average FCI confidence (AVGconf).

2) ***Confidence level for Right/Wrong answers***: can be contrasted at both FCI test times. For instance, are students significantly more confident of correct answers at the end of the semester? Also, are students more confident in right than wrong answers before/after instruction? Here again, confidence gains can be normalized. To find the normalized average confidence gain, the term T in equation 1 must simply be replaced by the average right FCI confidence (Rconf) or average wrong FCI confidence (Wconf).

3) ***Weighted FCI*** score. Assuming that a 5 point Likert scale can be treated as a continuum (implicitly done when performing t-tests on Likert scale data for instance), we can associate a numerical value to each level of confidence and construct a confidence "weighted" FCI score. To see how this works let us attribute 1 point for a correct answer, and –1 point for an incorrect answer. Levels of confidence are multiplicative values (or

weights) corresponding to the student confidence level: 0 on the scale indicating "guessing" and 4 indicating "very confident". A student entering a good answer with maximum confidence gets 4 points (1 x 4) whereas a student entering a wrong answer with maximum confidence receives –4 points (-1 x 4). Students that are not at all sure of an answer (i.e. confidence level 0) such as students that are guessing, get 0 points regardless of whether the answer is right or wrong. The 2-point true-false representation of students conceptions can now be mapped on a 9-point pseudo-continuum: from highly confident in a misconception (-4) to highly confident in a correct conception (+4). Resulting total weighted scores for the 30 FCI items therefore vary between –120 and 120. Differences in *weighted* FCI score across all groups can then be compared between both testing occasions. Here again, weighted FCI gains can be normalized by replacing T in equation 1 by the weighted FCI score (wFCI) yielding:

$$wg = (\text{Pre } wFCI - \text{Post } wFCI\,)/\,(120 - \text{Pre } wFCI) \qquad \text{Eq.2}$$

Taken together, these four confidence measures may address some of the concerns raised by the interpretation of FCI scores (Henderson, 2002; Steinberg & Sabella, 1997; Huffman & Heller, 1995). For instance, a student guessing a right answer would not attribute high confidence to an item. Therefore, a portion of false positives (students guessing a right answer) would become identifiable. Furthermore, these measures are more comprehensive as they assess *cognitive* (conceptual) *and non-cognitive* (confidence) changes giving a broader palette of factors that may affect learning.

ConcepTest data

Since many ConcepTests were presented to students during the semester, a collection of statistics relating the average percentage of correct answers when first presented with a question as well as the average percentage of correct answers after peer discussion. Other descriptive data include the ratio of questions having decreased in correct answers after instruction. Data was also collected with respect to the number of questions initially receiving less than 35% of correct answers and questions initially receiving above 80% of correct answers. This data will be presented at the end of chapter 4.

Student appreciation questionnaire

To get a better idea of how *Peer Instruction* students responded to the method, a seven item survey was presented to students during the last lecture. Students had to use a 5 point Likert-type scale (completely disagree, disagree, neutral, agree, completely agree) in answering the following questions:

1) *Peer Instruction* (PI) helped me recognize what I misunderstood
2) PI showed me that other students had misconceptions similar to mine
3) I actively discuss problems with my classmates
4) Convincing other students helps me to understand concepts
5) The mini-lectures help to clarify the concept for me
6) PI helps to learn better than traditional lectures
7) If I had the choice between a PI course and a traditional course I would choose PI

Both the flashcard and the clicker groups were asked to respond to this survey using the clickers. Since it was the first time that the flashcard group had access to the clickers, the following additional question was also asked to the flashcard group:

8) If I had clickers instead of flashcards I would have participated more

Sample

Participants in this study consisted of a cohort of 121 students following first semester NYA physics, an algebra-based introductory course to Newtonian mechanics. Students were pseudo-randomly assigned by the registrar to all 3 groups as all first semester students are assigned by the registrar to a teacher. Each of the three groups had approximately 40 students (flashcards: n=42; clickers: n=41; control: n=38). However, the FCI data collected in each group differed from the total numbers as some students wrote the FCI at the beginning of the semester but not the end or vice versa, and not all students initially registered completed the final exam. The following table shows the number of students in each section having pre and post FCI data as well as exam data.

Table 2.1 Number of students per section having complete FCI and exam data

	Clicker (n=41)	Flashcard (n=42)	Control (n=38)
Pre & Post FCI	35	34	22
Exam	40	39	35

Although the population was captive, participation remained voluntary. All participants were asked to complete a *Consent and Confidentiality* form (Appendix I). If a student did not desire to participate in the study, measures would have been taken in the first two weeks to insure transfer into another introductory physics section. However, all students chose to participate.

Analysis

The design of this study was chosen to render the analysis as simple as possible so it may be easily followed by all interested -particularly, non-research, teaching oriented- faculty members. Thus, the analytic design focuses primarily on finding averages and significant differences between averages using simple t-tests. For instance, to establish whether *Peer Instruction* is more effective than traditional instruction, both *Peer Instruction* groups (clicker group and flashcard group) were pooled and their averages on the exam and FCI gains were compared and significant differences were sought using t-tests. To determine whether using clickers offers a learning advantage, both *Peer Instruction* groups' (flashcard and clicker) averages on the exam and FCI gains were compared to the control section averages and a t-test was used to find whether significant differences existed. Since confidence data present many derived measures and that this study design provides at most 2 degrees of freedom, Bonferroni corrections were used when more than 2 t-tests were used.

Chapter 3

Peer Instruction at John Abbott College: An account of the Fall 2005 Physics NYA experience

This chapter addresses the first empirical question: Can the Harvard *Peer Instruction* approach be implemented in a Cegep context? To this effect, a brief case-study like description of my *Peer Instruction* implementation at John Abbott is presented. Why a case-study? Case-studies are warranted when a process is of sufficient complexity that its underlying variables cannot be controlled for. Those working in large institutions such as John Abbott College (5500+ students, 450+ teachers, not counting administration and support staff) know that changes are quite complex to implement. Beyond the inertia due to its size, there are many variables –some hidden and some apparent- that create resistance to change in such large institutions. The pleasant surprise in this study was the unparalleled flexibility encountered in trying to implement *Peer Instruction.*

Institutional Constraints: College's reception of the proposal

John Abbott college's science program has a policy of 'equity between sections of a same course' to insure that all students enrolled in a course get similar instruction. Students in all 12 sections (n≈500) of the Fall 2005 Physics NYA course (algebra based mechanics course) had the same laboratories and a common final exam. My initial concern in trying to implement *Peer Instruction* was that it would be refused by my departmental chair on the grounds that as it differed from what all other instructors were doing and that equity between sections could not be assured. However, the chair wrote off *Peer Instruction* as a different 'teaching style', since the course content would be the same (differing only by conceptual emphases), the laboratory experiments would also be the same and the students would be subject to the same final exam. That is, equitable need not imply identical. With my department's green light, I proceeded to the Science Program Dean's office to see whether he would support the idea.

I thought of the many reasons the Dean of Science could give me objectively to refuse -or at least indeterminately delay- the study. Having rehearsed each point and thought out equally objective counter arguments in favour of the study, I knocked on the Dean's door. As Dean Schmedt listened to the idea, he presented none of the objections I had carefully rehearsed. In fact, not only did he not object, he suggested creating a new science program fund to support the study and other initiatives like it. After all he said, this would not benefit the physics department alone; biology and chemistry could make use of it too. The study would also be useful in thinking about whether the college's new science building should be wired for clickers and receivers. The only thing left was to get the Academic Dean's approval. Hmm, I thought, I knew there was a catch…

Dean Thorne the Academic Dean - as the Dean of Science and the physics department chair before him - received the idea with great enthusiasm. He released sufficient funds to purchase 90 clickers, 3 receivers and the related software (3500 $US) as well as a laptop (2500$, since the computers available from the AV services forbid any program installations) that would be devoted to 'the clicker project'. All that was left was to clear the project through the college's R&D committee. Having answered the standard questions relating to consent and confidentiality, a number of familiar faces from the R&D committee looked at me with interest as I described the 'between the lines' details of the proposal I had submitted. One of them claimed that they would like to be back in school, and oh how things had changed!

As I write about this R&D committee encounter, it strikes me that I have omitted an important part of the context: myself. Many times, I have read about the importance of the observer in the description of events and that a full description requires a description of the describer. I suppose that my understanding of this is somewhat like that of an experimental physicist trying to learn about all the features and limitations of an apparatus before using it in an experiment. Here, the apparatus used for description is myself. Yet, it is a fine line between talking about oneself and navel gazing, and such is the tightrope I will try to walk through in the following lines.

My smooth stroll through the R&D committee was maybe not only due to the common sense displayed by the current project. I had been in front of this committee a number of times before. In fact, I clearly recall my first encounter with a R&D 'firing squad' made up of seasoned teachers and support staff coming down on the new 26 year old teacher that I was. Having just finished a graduate degree in particle physics, I was trying to find out what interacted with students' understanding. Were there different personalities or intelligence profiles? I was asking the committee for 200$ to purchase psychometric questionnaires to find out the differences and similarities between teacher and student profiles. I cannot forget the nastiness of one (evidently non-science) teacher. Why was it always the science teachers asking for money?! Their departments have the greatest budgets! Having politely pointed out that these budgets cover science equipment and related expenses, not psychometric tests for research purposes, I continued to present the study whose merit had never really been challenged. The R&D chair later apologized for the behaviour of the member and let me know that the committee had decided to retain the study and provide the requested 200$.

The next time I encountered the committee was for my PhD work in Educational Psychology. Faces on the committee were now more familiar. Questions were asked and I was prompted on different issues. Having been through McGill ethic's board prior to John Abbott's R&D, all questions were thoroughly and satisfactorily answered. The committee was quite please with the project and offered their best wishes of success in the completion of the study and the degree. The following encounter with the committee was for this project. By this time, four years had elapsed since I was hired, my PhD dissertation was completed and I was attempting to use what I had learned in education to better the learning of my students and bring the teaching into the 21st century with a bunch of high tech gizmos. I could not presume that such a positive reception would be shared by new faculty members trying to implement this approach in other colleges. Indeed, I had acquired in a few years sufficient credibility in front of peers, administrators and committee members that most probably contributed to the enthusiastic response observed. Now, I will stop as the extended focus on my navel has caused me to fall catastrophically from my tightrope…

Modifications to course structure

Using *Peer Instruction* with clickers in the classroom requires a minimum amount of changes, as would any new Information and Communication Technology (ICT). To present students with ConcepTests that will allow clicker votes, one needs to write or import conceptual questions either in the clicker software or in the more common Microsoft PowerPoint. Many ConcepTests can be found either online though the rich Project Galileo website at Harvard (http://galileo.harvard.edu/) or through textbook publishers that now package 'clicker questions' with their textbooks. I have used primarily questions from the Galileo site, publisher provided 'clicker questions' written by Randall D. Knight (2004) and a few questions that I have written myself. Using clicker questions however led me to make the following two changes.

The first change is quite profound. Indeed, in identifying which conceptual questions to use, one is forced to identify which basic concepts are central. This may seem trivial: aren't learning outcomes always identified before a class is given? Unfortunately, physics is often disguised in elaborate mathematics that hides the simplicity and power of the basic concepts. Instructors seeing students struggle with the mathematics, shape the learning outcome around the observed difficulties and give more emphasis to mathematical problem solving than to basic concepts. In trying to implement *Peer Instruction,* one is forced to reflect on the expected ***conceptual*** learning outcomes. What basic concepts should students understand? What is critical, and what is secondary? A selection of conceptual questions is the first step in critically rethinking what basic concepts students should learn from an introductory physics course. This clearly constitutes a sea change from traditional physics instruction.

The second change is more superficial yet more time consuming as well. Since clicker questions are placed in PowerPoint, then one might as well present the entire course on PowerPoint. Indeed, it becomes cumbersome to turn on the projector, bring the screen down, project a question, then shut the projector down, reel the screen back up and return to the blackboard behind it. The advantage of having an entire course on PowerPoint is that students no longer need to rush to write down notes from the board; all PowerPoint notes can be placed online and downloaded. Thus, students can pay attention to the instructor without fearing to miss anything on the board. However, although writing an entire course on PowerPoint may have advantages, the time commitment required may act as a prohibiting factor for instructors seeking to implement the approach. Indeed, one must plan 2 hours of preparation for each hour of class, and possibly more if one types slowly. So is the advantage of PowerPoint lectures solely a student learning advantage placing the entire burden on the instructor? Not really. It turns out that PowerPoint lectures need only small adjustments from term to term. Thus, future course preparations can be significantly reduced by having an existing PowerPoint course. Only 15 to 20 minutes of new preparation time are needed for using previously prepared PowerPoint class notes. Additional instructor advantages of digital presentations include avoiding the ubiquitous chalk residue found everywhere after a lengthy problem session on the board.

Other changes related to the clicker technology include familiarization with the clicker hardware and software. For instance, the clickers used at John Abbott College are manufactured by GTCO Calcomp. These clickers are quite sturdy and require little if any maintenance. One can install the clicker software from a CD provided with the hardware and updates are sent and easily downloadable from the GTCO Calcomp site (requires a login and password). It is strongly recommended that all interested instructors setup the clickers and receivers and try them a few times before attempting to use them in class. The following pitfalls were encountered when using the clickers at John Abbott.

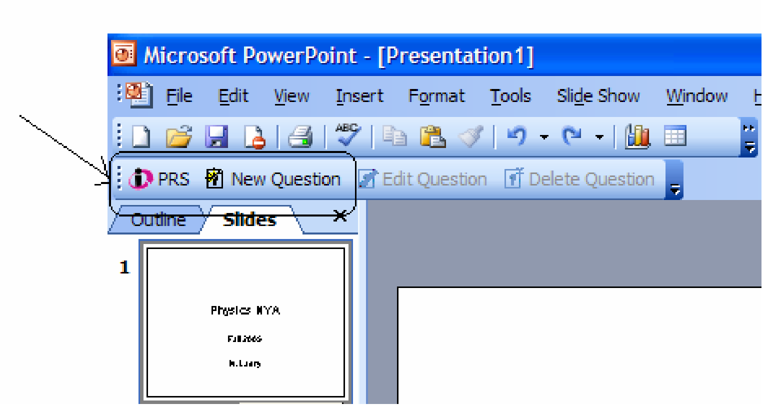
Hardware issues

Receivers manufactured by GTCO Calcomp must be plugged into a COM port. A clear and easy to use schema provided shows how to make all connections. However, new laptop computers have replaced analog COM ports by digital USB post. Since clicker data receivers cannot be plugged into the USB port, an analog-to-digital COM-USB converter must be purchased. Having received the clickers only a week before classes, an emergency phone call to the manufacturer ended with a suggestion to purchase a Keyspan© COM-USB converter. The problem would be solved rapidly thanks to their 'overnight shipping'. It was a long night indeed as the converter arrived from the US two weeks later, having been delayed at customs for more than 10 days…

Software issues

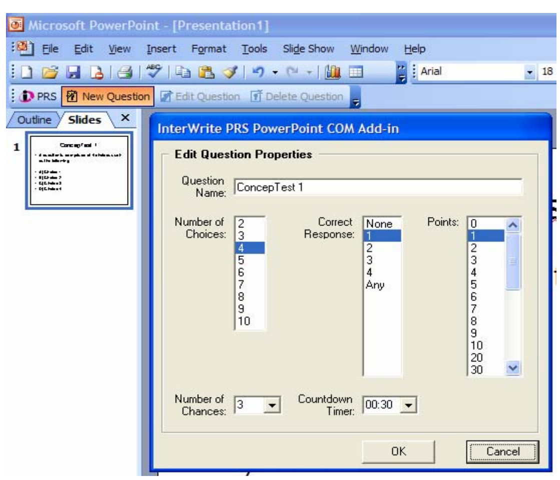
The software provided is quite user-friendly. Indeed, it simply installs an icon in PowerPoint which allows for the quick creation of a clicker question in any slide.

Figure 3.1 Interwrite PRS –clicker software- in PowerPoint

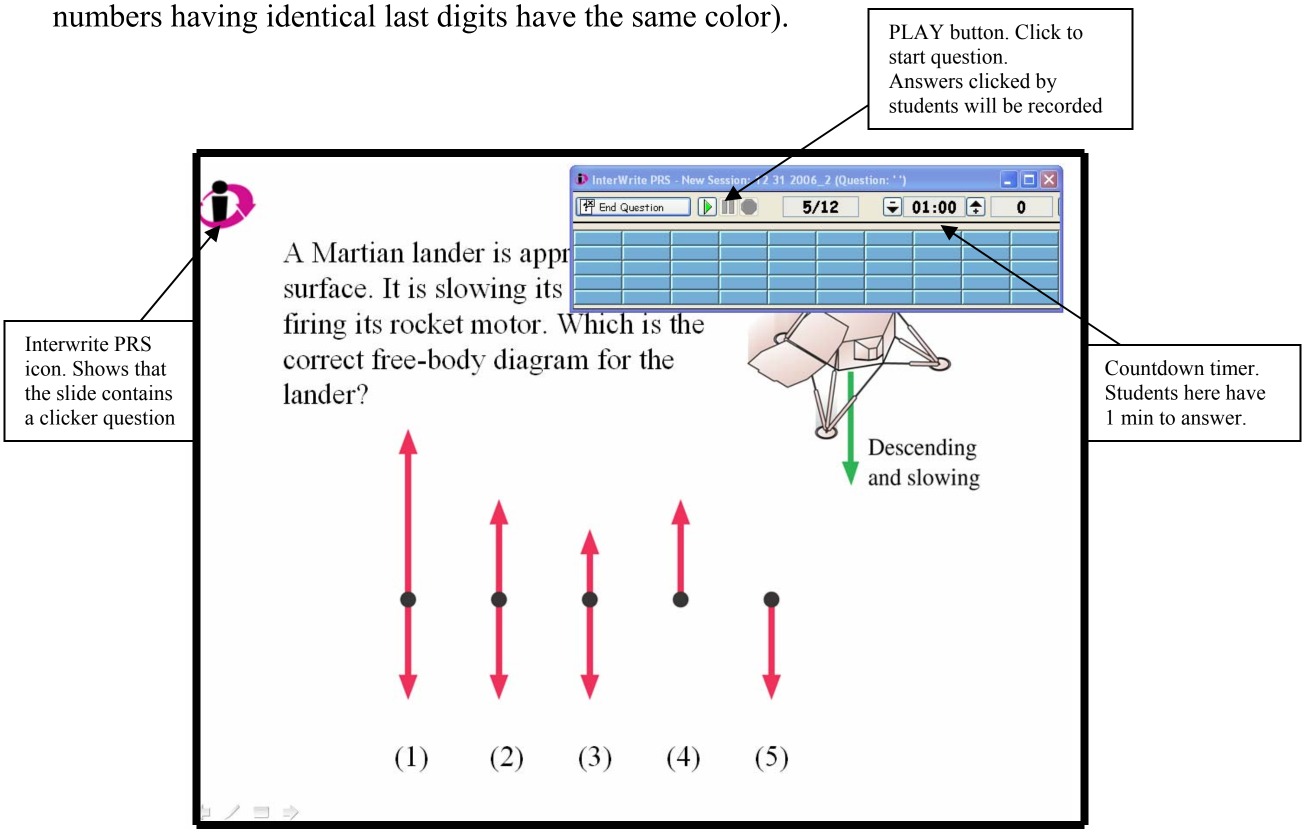


To create a new question one need only click on the 'New Question' button and a menu appears prompting the user among other things to state the number of choices in the question, the correct answer, and the amount of time students have to answer.

Figure 3.2 Creating a new question in PowerPoint



Once a question has been created, an Interwrite PRS icon (bold **i** with 2 pink arrows circling it) appears in the top left corner of the PowerPoint slide. When the slide with a prepared clicker question is presented, a menu with a green 'play' button will appear. To start the question, press on the green arrow. The timer will countdown and each blue rectangle will display the ID number of the clicker whose data has been received (all numbers having identical last digits have the same color).



The complexity of the software as can be seen by the number of features it comprises does not take away from its user-friendliness. Indeed, using this software was quite straight forward. If any problems arose, the company's technical support was available and well prepared to answer questions. The following problems were encountered when using this software.

1) When presenting a ConcepTest in class, one must make sure that all animations are withdrawn from the question slide. For instance, most of the slides I present use a simple 'appear' animation which reveals points one by one. If a question slide has any animation, it will malfunction when presented. Indeed, the clicker software opens when a

question slide is presented. However, only the question appears as the presenter must click once for each choice to appear. The clicking interferes with the clicker software as it interprets that the question is over and that the correct answer should be displayed.

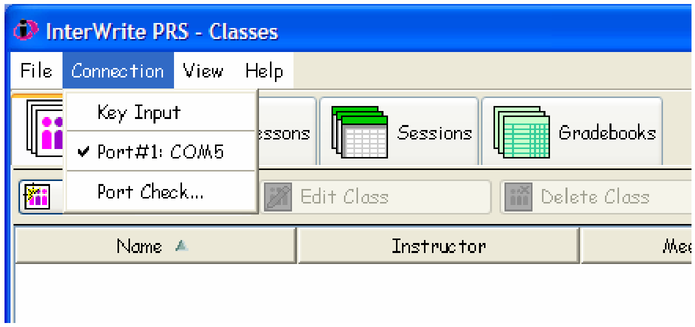
2) In *Peer Instruction* a question is presented twice and students should be able to vote twice. For this to occur, each question was presented on 3 different slides. The first allowed the students to vote the first time. The second, allowed for the second vote and the third showed the correct answer.

3) It is preferable that students not see the histogram of results after the first vote so as not to be influenced by what others think. Having both questions in 2 different slides does not get rid of the problem. To prevent the histogram from appearing after the first vote, one must either deactivate it in the software or cancel the computer input to the screen. Whereas deactivating the histogram from the settings solves one problem it creates another in not letting students see the final distribution of answers, nor compare the evolution gained through discussion. Although tedious (must be done manually after each first vote), cancelling the computer input to the projector is preferred since the histogram can be made to appears only on the instructor's laptop after the first vote and can then be projected for all after the second vote.

4) When a PowerPoint presentation is started before the clicker hardware is fully connected, all voting malfunctions. Indeed, when a presentation is started, the clicker software opens automatically. If no receivers are plugged, then no receivers will have been recognized and all data sent by clickers will not be processed. All hardware must therefore be installed before a presentation is started.

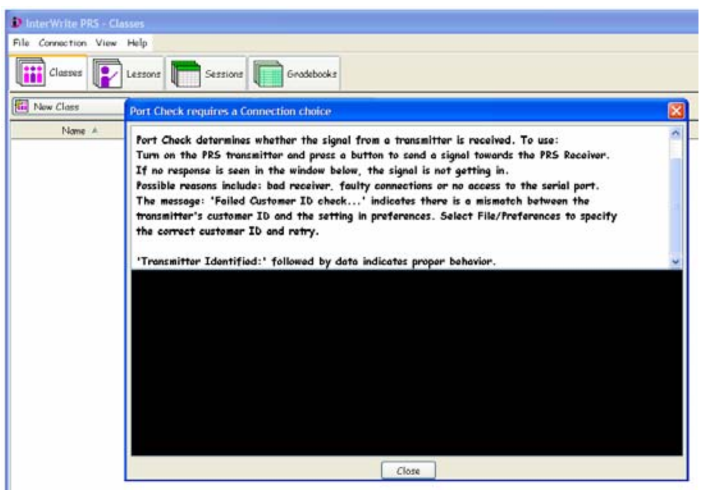
5) There are a few other instances when the receivers have not been recognized by the software (including disconnection of the COM-USB converter or default USB port assigned). To make sure that receivers are recognized before starting a presentation, one should open the clicker software 'Interwrite PRS' from the start menu. Within this environment, click on connection, choose a port and go to port check.

Figure 3.3 Interwrite PRS software: detecting the receiver



The port check will open another window which will display the clicker ID number if the receiver is properly connected. If the wrong port has been selected, select another port and go through another port check until the correct port is selected and clicker data is properly received and displayed in the black background.

Figure 3.4 Interwrite PRS software: port check



It is suggested that instructors go through port checks systematically before opening a presentation so as to avoid embarrassing instructional dead-time where software pitfalls destroy the momentum built up in the first part of the class.

Feasibility of modifications

The modifications presented in this chapter should alert interested instructors on a number of points. First, administrators can readily buy into the idea of *Peer Instruction* as clickers provide an ideal window into increasing the presence of technology in the classroom. However, one must carefully evaluate policies in different institutions as these may widely differ between institutions. Second, as with any new Information and Communication Technology, much work is initially required for implementation. Yet, this work does pay off as future preparation times are greatly reduced, student attention is increased and much data can be saved for later analyses and allow one to rethink or reformulate questions.

In terms of course content, most of the ConcepTests were easily imported into PowerPoint. Some clicker questions are provided with textbooks (eg. Knight, 2004) and these may even be written in PowerPoint. Conceptual questions also exist in chemistry and biology and are available from the Harvard Galileo website. Therefore, one must conclude that *Peer Instruction* is quite feasible at the Cegep level.

Reception by other instructors

The physics department at John Abbott College has 14 full-time professors on staff. More than half of the full-time department (8/14) members are new instructors having replaced retired faculty since 2000. Most professors manifested much interest and curiosity when presented with the *Peer Instruction* approach. Although none as yet have opted to use clickers in their classrooms, 3 are planning to do so next semester and 6 are currently using flashcards or other hand raising media (such as 6”x10” whiteboard with markers). Therefore, it is fair to state that the physics professors of John Abbott College have warmly welcomed *Peer Instruction.*

Instructors in other departments have learned about the method from presentations given at the college and from word of mouth. In the chemistry department, one professor has successfully used the clickers in his introductory course, and is looking forward to repeating the experience. In the nursing department, another instructor is actively looking into using the method in her courses next semester. Numerous other instructors have inquired about the hardware and may opt to use it in their classrooms.

Reception by students

Students warmly welcomed using clickers in the classroom. Interestingly, the students in the flashcard section were also quite content with using flashcards. However this contentment tapered when these students realized the other section was using clickers. To gauge the appreciation of the method in both the clicker and flashcard section the following seven questions were asked:

1) *Peer Instruction* (PI) helped me recognize what I misunderstood
2) PI showed me that other students had misconceptions similar to mine
3) I actively discuss problems with my classmates
4) Convincing other students helps me to understand concepts
5) The mini-lectures help to clarify the concept for me
6) *Peer Instruction* helps to learn better then traditional lectures
7) If I had the choice between a PI course and a traditional course I would choose PI

A table is presented below for each question. Answers were collapse onto 3 categories: agree/strongly agree; neutral; disagree/strongly disagree. To determine whether students ***agreed*** with a statement more than would be expected by chance (2/5 or 40%), a binomial probability (agree $p=0.4$; not $q=0.6$; $n=30$) was calculated. Statements followed by an asterisk (*) agreed with $p<0.05$ whereas 2 asterisks (**) signify $p<0.01$.

Table 3.1
Q1: *Peer Inst helped me recognize what I misunderstood*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	66**	31	3
Flashcard	58*	27	15

Table 3.2
Q2: *PI showed me that other students had misconceptions similar to mine*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	82**	12	6
Flashcard	73**	22	5

Table 3.3
Q3: *I actively discuss problems with my classmates*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	59*	38	3
Flashcard	50*	35	15

Table 3.4
Q4: *Convincing other students helps me to understand concepts*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	47	38	15
Flashcard	58*	30	12

Table 3.5
Q5: *The mini-lectures help to clarify the concept for me*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	85**	12	3
Flashcard	73**	12	15

Table 3.6
Q6: *Peer Instruction helps to learn better then traditional lectures*

	Agree (%)	Neutral (%)	Disagree (%)
Clicker	50*	41	9
Flashcard	58*	24	18

Table 3.7
Q7: *If I had the choice between a PI course and a traditional course I would choose PI*

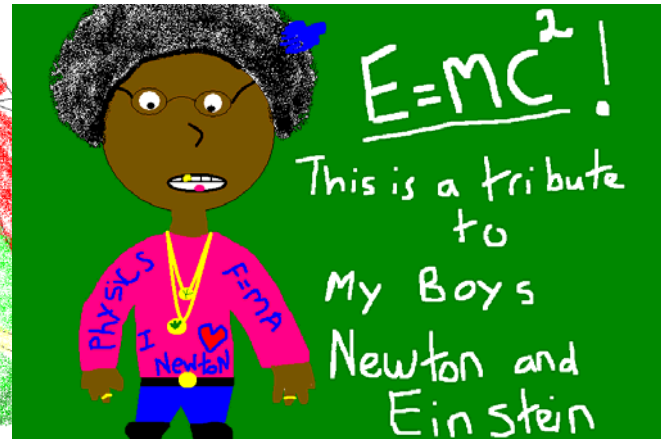
	Agree (%)	Neutral (%)	Disagree (%)
Clicker	83**	10	7
Flashcard	71**	9	20

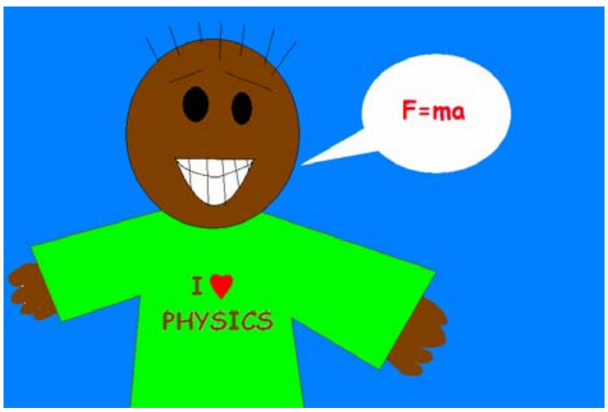
Table 3.8
Q8: *If I had clickers instead of flash cards I would have participated more*

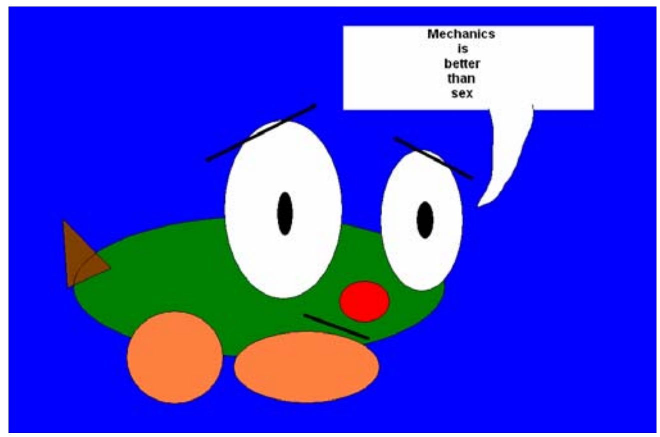
	Agree (%)	Neutral (%)	Disagree (%)
Flashcard	**61****	**11**	28

These data show that students responded positively to *Peer Instruction* by significantly acknowledging its advantages as an instructional approach (Q1-5) and by preferring it to traditional instruction (Q6,7) . Students also seem to appreciate the clickers more than flashcards as can be seen in question 8, asked only to students in the flashcard section.

Unsolicited student feedback was also found in the form of computer doodles made in Microsoft Paint and placed on physics laboratory computers as screen savers. The pictures below were found on the physics lab computers screens after *Peer Instruction* students had left. These pictures were not present before students entered the lab.







Taken together, these unsolicited student pictures complement the previous survey data in supporting the claim that students warmly welcomed *Peer Instruction* in the public Cegep context.

Chapter 4

Effectiveness of *Peer Instruction*

The purpose of this chapter is twofold. The first objective is to determine whether *Peer Instruction* is more effective than traditional lecturing in Cegep contexts. The second objective is to isolate the specific contribution of the technology to instruction. That is, does the use of clickers procure students with a learning advantage? To this effect, numerous data were collected in all three groups: (Group1 = clickers; Group2 = Flashcards; Group3 = Control). This data includes conceptual FCI data before and after instruction, levels of confidence for each FCI item and final exam data. Results of various analyses are presented below.

Effectiveness of Peer Instruction vs. Traditional lecturing

Conceptual Learning

In this part of the study both *Peer Instruction* groups (clicker group and flashcard group) were merged and learning measures were compared. The following table displays the FCI Pre-test score, Post-test scores, normalized gains for both *Peer Instruction* groups and the control group. Also shown below are p-values obtained using t-tests to determine whether the difference in averages is significant and if so at what level.

Table 4.1
FCI data for *Peer Instruction and* traditional control group

	<Pre-test> (%)	**<Post-test> (%)**	**g** (norm. gain)
***Peer Instruction* (n= 69)**	42.6	68.6%	0.50
Control (n=22)	46.0	63.3%	0.33
t-test (2-tailed) p	0.427	0.283	***0.008***

These results show that although no significant difference exists between groups before instruction (p=0.427) the *Peer Instruction* group gained significantly more conceptual knowledge after instruction (p=0.008) as measured by the FCI. This result shows unequivocally that *Peer Instruction* enables more conceptual learning than traditional instruction. Note that the results found here replicate results found by Mazur (1997) on conceptual learning and by Hake (1998) in the difference between non-traditional ‘interactive engagement’ methods (including *Peer Instruction*) and traditional instruction.

Traditional problem solving

Physics instructors often hesitate to use non-traditional methods such as *Peer Instruction.* One of the frequent concerns is that the time spent on concepts will take away from the problem solving skills that students are expected to have and display on summative assessments such as the final exam. The following table shows the average grades on the Fall 2005 common final exam as well as the p-values found by using a t-test to compare the exam averages of students between groups.

Table 4.2
Common final exam data for *Peer Instruction* and traditional control group

	Exam Avg (%)
***Peer Instruction* (n= 79)**	68.0
Control (n=35)	63.0
t-test (2-tailed) p	0.21

These results show that *Peer Instruction* students show non-significantly better results (p=0.21) on the exam. Therefore, although more time is spent on conceptual learning and less time is spent on algorithmic problem solving, students in *Peer Instruction* groups do not have lesser problem solving skills. This may be due to the positive contribution of conceptual knowledge in traditional problem solving. That is, one must spend more time to learn many algorithms by rote than is required with solid conceptual knowledge. Taken together these results on conceptual learning and traditional problem solving clearly demonstrate that *Peer Instruction* is a more effective approach to learning physics.

The effect of clickers on learning

To determine the effect of clickers on learning, the FCI pre-test, FCI post-test, FCI normalized gain and exam data are compared below for both *Peer Instruction* groups:

Table 4.4
The effect of clickers: difference in learning data between flashcard and clicker groups

	PreFCI /30	**PostFCI /30**	***g***	***Exam (%)***
Clickers (n= 35)	**11.9**	**19.9**	**0.486**	**69.8**
Flashcards (n=34)	**13.6**	**21.3**	**0.520**	**71.6**
t-test (2-tailed) P	**0.209**	**0.351**	**0.745**	**0.630**

These results shows that both groups did not differ significantly in FCI score at the beginning of the semester (p=0.209) or at its end (0.351). Interestingly, the use of clickers does not add to the amount of conceptual learning or the problem solving skills. Indeed, although clickers have been reported to have a motivating influence, over the course of a semester no significant differences were found in conceptual learning (p = 0.745) nor in problem solving skills (0.630). This implies that *Peer Instruction* is an effective instructional approach which is independent from the use of technology such as clickers. Thus, the technology must not be confounded with the pedagogy.

Effectiveness of Peer Instruction: the role of proficiency

One may contend that what works at Harvard may not necessarily work in a public college setting. The question addressed in this section is whether student aptitudes in physics, or equivalently their proficiency level, contribute to the effectiveness of *Peer Instruction.* To this effect, the initial proficiency level of all students was associated to their FCI score before instruction. Students from all groups were pooled and a median FCI score before instruction of 12/30 was found. Two groups were then constructed by taking all students at the median pre-test FCI score or below in one group, and all those above the median in another. Normalized gains for high and low proficiency students were then compared and differences in average normalized gains between groups were sought using a t-test. The following table illustrates the results.

Table 4.3
Effect of student proficiency on learning in *Peer Instruction* and control

	PreFCI ≤ Median *G*	**PreFCI > Median *g***	***t-test (2-tailed) p***
***Peer Instruction* (n= 69)**	**0.387**	**0.672**	< ***0.00001***
Control (n=22)	**0.264**	**0.383**	0.337
t-test (1-tailed) p	0.07	***0.00022***	

This data is quite revealing. A difference is found between low proficiency students and high proficiency students in both sections. This is somewhat consistent with the constructivist claim that new knowledge is constructed from prior knowledge; the inference being: the greater the prior knowledge the greater the learning. In the *Peer Instruction* group, the difference between both proficiency groups is very large (0.387 vs 0.672) and quite statistically significant (p < 0.00001). Thus, *Peer Instruction* works particularly well for students with higher proficiency levels. Indeed students with higher proficiency levels in *Peer Instruction* achieve significantly more conceptual learning (0.672 vs 0.373; p=0.00022) than high proficiency students in the control section.

These results also show that low proficiency students perform non-significantly better (p=0.07) in the *Peer Instruction* group. The fact that no difference was found can be explained by the fact that there were only 9 low proficiency students in the control section and that the p-value obtained may have been significant with the greater statistical power provided by a larger sample.

Students' confidence in concepts

The next question investigated is the difference between traditional lecturing and both *Peer Instruction* groups on students' confidence in concepts (henceforth referred to as concept-confidence). The following 3 tables show the different average concept confidences on the FCI pre-test, post-test as well as the normalized average confidence gain for both the *Peer Instruction* and the traditional groups. A t-test showing the 2-tailed probability for the difference between pre-test confidence and post-test confidence is also shown for each section.

Table 4.5
Average FCI concept-confidence levels

	PreFCI AvgConf (max 4)	**PostFCI AvgConf (max 4)**	**AvgConf g (norm. gain) (-1,1)**	***Pre-Post t-test (2-tailed) p***
Clickers	2.5	3.1	0.37	***0.0009***
Flashcards	2.7	3.2	0.35	***0.008***
Control	2.7	3.2	0.35	***0.016***

This data shows that students in all three sections had similar concept-confidence levels in before and after instruction in all three groups, regardless of instruction format. Furthermore, students in each section showed a significant increase in confidence after instruction. This implies that students are significantly more confident about physics concepts after instruction than they were before instruction, and that this is true regardless of instruction type. The remaining question is whether the increases observed are due to increases in concept-confidence for *correct* or *incorrect* answers. The following two tables illustrate the average right answer and wrong answer confidence found before instruction, after instruction as well as the gain. A 2-tailed t-test for the difference between pre-test and post-test confidence is also provided.

Table 4.6
*Average FCI concept-confidence levels for **Right** answers*

	PreFCI RConf (max 4)	PostFCI RConf (max 4)	RConf g (norm. gain) (-1,1)	*t-test (2-tailed) P*
Clickers	2.7	3.1	0.32	***0.031***
Flashcards	2.8	3.3	0.38	***0.012***
Control	2.9	3.3	0.40	***0.017***

Table 4.7
*Average FCI concept-confidence levels for **Wrong** answers*

	PreFCI WConf (max 4)	PostFCI WConf (max 4)	WConf g (norm. gain) (-1,1)	*t-test (2-tailed) p*
Clickers	2.3	2.7	0.266	0.168
Flashcards	2.5	2.7	0.12	0.344
Control	2.6	2.9	0.21	***0.011***

These data and results are quite interesting. First, average confidence levels for wrong answers are generally inferior to those for right answers whether before or after instruction. After instruction, the right answer confidence level increase significantly in all sections. As expected, students are more confident in physics concepts after instruction. Interestingly, confidence in wrong answers also increases after instruction in all sections and significantly (p=0.011) in the clicker section. Not displayed in these tables is the lack of significant difference found between groups in pre-test confidence, post-test confidence and confidence gain both for right and wrong answers. This lack of difference implies that students gain equally in confidence with all of the approaches.

Confidence weighted FCI gain

The remaining confidence measure assessed is the confidence weighted FCI gain. As presented in chapter 2, this measure uses the confidence as a multiplicative weight (0 to 4) affected to each FCI item (correct = 1 ; incorrect = -1). Thus, students highly confident in a correct answer (1x4) are distinguished from students not very confident or guessing a right answer (0x4 or 1x4). Similarly, this measure distinguishes between students highly confident in a wrong answer and students not sure of a wrong answer. Thus, the 0 to 30 score on the FCI is projected onto a -120 to 120 concept-confidence displaying scale.

Table 4.8
Average confidence weighted FCI (wFCI)

	Pre wFCI (max 120)	Post wFCI (max 120)	wFCI g (norm. gain) (-1,1)
Clickers	-6.1	38.6	0.392
Flashcards	-4.0	50.0	0.467
Control	0.9	36.0	0.305

Students in all three sections start at around 0 on the confidence weighted FCI scale, and although not displayed above, no significant difference in weighted FCI was found between any pair of groups before instruction. After instruction however, the *Peer Instruction* groups (pooling flashcard and clicker groups together) gained significantly more (p=0.028) than the control group. Yet, when comparing the both *Peer Instruction* groups, no significant difference was found (p=0.235) between the flashcard group and the clicker group in weighted FCI gain. These results confirm the superiority of *Peer Instruction* over traditional methods even when taking confidence into account. Furthermore, these results also confirm that using clickers instead of flashcards provides no significant learning advantage.

Using Clickers: In class ConcepTest data

The following section gives some sample descriptive statistics of the ConcepTests used in class. To begin, over the 15 week semester, an average of 3 to 4 ConcepTest questions was given per course. Since lectures lasted approximately 75 min and each *Peer Instruction* cycle (see fig 1.4) lasts between 15 and 20 minutes, 3 to 4 ConcepTest questions was found to be instructionally adequate. The following table shows the initial percentage of *correct* ConcepTest answers, the percentage after peer discussion, the absolute gain and the normalized gain.

Table 4.8
In class ConcepTest data: % correct answers before & after discussion

	Pre	**Post**	**Gain**	***g* *(-1,1)***
Correct answers (%)	51.5	62.2	10.7	0.24
Standard Dev.	17.4	17.6	12.4	0.22

This data shows that the increase after discussion is relatively small (10.7%). Yet, after the discussion, all students are explained what the correct answer is and why each of the other answers are wrong. The great conceptual learning gains observed in *Peer Instruction* may be due in part to the in-class discussions but also to the cognitive conflict resulting from the realization that a choice of answer made was wrong. Therefore, one may be conservative with expectations of gains from in-class discussions. Not displayed in the table above is the finding that 9% of ConcepTests presented in class displayed correct answers *lower* after peer discussion than was initially given before discussion.

In *Peer Instruction,* one must pay careful attention to questions initially having less than 35% or more than 80% of correct answers. In this study 18.2% of ConcepTest given were answered correctly by 35% of students or less, leading the instructor to return and revisit the concept. On the other end, 20.5% of ConcepTests given were answered correctly by 80% of students or more, leading the instructor to explain remaining misconceptions and proceed to the next concept. These numbers best describe the use of in-class ConcepTests when implemented at John Abbott College.

Chapter 5

Discussion of Result

Can Peer Instruction be implemented in Cegep contexts?

Reception by Cegep community

In returning on the narrative account and other descriptions presented in the third chapter, it seems clear that the *Peer Instruction* approach was successfully implemented at John Abbott College. The approach fit in with the college's institutional constraints. For instance, the physics department chair did not see in *Peer* Instruction an approach that led to a gap in 'equity between sections of a same course'. Furthermore, both the Dean of Science and the Academic Dean welcomed the project as an opportunity to test new forms of technology in the classroom. Teachers also received the method very positively as a majority of instructors in the physics department currently use some form of *Peer Instruction* (use of in-class ConcepTests answered using clickers, flashcards, 6"x10" individual whiteboards, or show of hands). Teachers from other departments have also taken notice of the method and some have used clickers in their classrooms while others reshape their courses in order to do so.

Students welcomed the approach as well. Data from the students' survey as well as the student computer doodles (illustrated at the end of Chapter 3) demonstrate the appreciation of students for *Peer Instruction*. Yet, one must also note that the students in this study were mostly first semester students. First semester students enter the college setting unaware of what teaching format to expect. It is unclear whether third or fourth semester students habituated by didactic instruction would have reacted as positively. Indeed, fourth semester students might have expected the teacher to 'just tell them' what physics to learn and that peer discussion is simply a waste of time. Therefore, the positive reception by students must be taken within a first semester context and the expectation for students later in their program to react as positively is unwarranted.

Feasibility of required modifications

Multiple modifications are required to carefully implement *Peer Instruction*. First, seminal changes must be done in the way one thinks about the course. Indeed, one is forced to reconsider -from a purely conceptual perspective- what the learning outcomes of a course are. Furthermore, the architecture of a course must also be modified. Didactic transmission of algorithms for various problem types must be replaced by a conceptual overview of the content which is gradually translated into mathematical formulation. Yet, the change that may be the most discouraging to instructors is the amount of time required to construct entire lecture presentations on digital slides thereby enabling smooth transitions between the lecture and the ConcepTests. It is suggested that interested instructors only write brief notes for some courses initially. A database of lecture notes could also be made available. In fact, requests could be forwarded to textbook publishers for point-form notes to accompany the book. Publishers already provide instructors with all the figures and diagrams included in the book. Course notes showing key concepts, figures and conceptual questions could be prepared by publishers. This would greatly increase the likelihood of using *Peer Instruction* in classrooms. Such a recommendation will be forwarded to the Mazur group at Harvard and to publishers.

Greater effectiveness of Peer Instruction over Traditional instruction

As expected from studies in American colleges and universities, *Peer Instruction* in Cegep enabled significantly more ($p=0.008$) conceptual learning than didactic lecturing. Yet, such a result may not be sufficient to convince certain instructors from adopting the method. Indeed, one of the frequently encountered objections is that given the time allotted to conceptual discussions, less time is spent on problem solving. Since students already have difficulty with physics problem solving, taking time away from their in-class problem solving activities would be unwise. In fact, quite the opposite was found. Although *Peer Instruction* students spent more time on concepts, they performed non-significantly ($p=0.21$) better than students in the control group with respect to traditional problem solving as can be witnessed by the similarity in final exam averages. Thus, although less time is spent in algorithmic problem solving, providing a solid conceptual background allows students to be more effective in problem solving.

No added effectiveness with clickers

One of the interesting and unexpected findings of this study is that the use of clickers does not provide any additional learning benefit to students. Previous users of clickers in university classrooms had reported benefits such as increased rates of attendance and decreased rates of attrition (Owen *et al., 2004;* Lopez-Herrejon & Schulman, 2004) since students may want to come in class to simply "play with the clickers". However, no data was found in this study to support that clickers have a motivating effect which increases conceptual learning.

The ubiquitous presence of technology implies that our classrooms will increasingly make use of new forms of Information and Communication Technologies (ICT). Yet, meta-analyses on the effectiveness of ICTs as a whole show relatively small effect sizes (Parr, 2000), comparable to other approaches such as homework or parent questioning (Sinko & Lehtinen, 1999). In finding no added effectiveness of clickers over flashcards, this study reminds us that technology is but a tool, albeit a very effective tool. This tool can be used to efficiently enable conceptual change; but it could equally be used to promote rote learning. Indeed, some publishers have created clicker questions that allow biology instructors to rapidly survey large amounts of definitions and other forms of declarative knowledge, pushing students to increase the amount of rote memorization required to pass their classes.

Peer Instruction with clickers does work better than traditional instruction; but it does not work better than *Peer Instruction* with flashcards. In fact, students in the flashcard section performed non-significantly better than those in the clicker section with respect conceptual learning ($p=0.745$), problem solving skills ($p=0.630$) and confidence weighted FCI gain ($p=0.235$). This implies that *Peer Instruction* is an effective instructional approach regardless of the means taken by students to report their answers. *Peer Instruction* is an elaborate pedagogical approach that places a strong focus on basic concepts, requires students to commit to a conception and provides a setting for peer discussion to sort out correct concepts from misconceptions. Clearly, the technology is not the pedagogy. Must clickers be abandoned then?

In fact, clickers should be greatly encouraged. At first glance, this conclusion may seem to contradict the previous finding. However, there are three main reasons why clicker use should continue to be encouraged. First and foremost, clickers are responsible for much of the attention given to the *Peer Instruction* approach. Indeed, much of the success of *Peer Instruction* implicitly rest on the use of clickers (Burnstein & Lederman, 2003, 2001) or more formally: Classroom Communication Systems (Abrahamson, 1998). Many instructors, including myself, have adopted the approach due to the appeal of increasing technology in their classrooms. Using *Peer Instruction* with clickers however forces instructors to reconsider their teaching, focus on concepts and thus fundamentally reshape their instruction. Since many instructors would not give proper attention to *Peer Instruction* were it not for the clickers, one must continue to encourage their use.

Second, using clickers in the classroom provides a number of teaching advantages. For instance, conceptual questions and their related data can be archived. Beyond data analyses and research questions that can be addressed, this data can be used to sort out useful ConcepTests from those that work poorly. Poor questions could be discarded whereas those of modest effectiveness could be reformulated. The core set of questions could therefore evolve from one semester to another. Using flashcards does not enable the instructor to collect any ConcepTest related data. Thus, reusing the same questions from semester to semester may differ in effectiveness from using questions that have been modified through field testing from one semester to the next. Since only one semester of implementation was compared in this study, no such differences were found although these differences are expectable over a few semesters.

The third reason for encouraging clicker use is to maximize the effect of peer discussion. Flashcards also require peer discussion; so what is the difference? When using flashcards, students discuss with their closest neighbours. Yet, adjacent students frequently have the same answer and the effectiveness of peer discussion is decreased. Currently, 2-way clickers with a LCD display are available. These clickers allow students to send data but also receive data from the instructor's computer (such as an acknowledgment of the reception of their vote). The display could also be programmed to show other information. To maximize the effect of peer discussions, one may program the response displayed to students so that it pairs students of differing conceptions. The response could then relocate a student to another seat in the classroom where the adjacent student holds a different conception. Using the clicker display to pair students holding different conceptions would thus maximize the effectiveness of the approach.

Some instructors may be aware of *Peer Instruction* methodology and willing to reshape their instruction to provide greater focus on basic concepts. Using clickers is not a *sine qua non* condition to using *Peer Instruction*. For instance, in some cases the budgets required to purchase clickers and related hardware may not be available, or passing the expense onto students may not possible or desirable. In this instance, *Peer Instruction* should be implemented with flashcards as it is the *Peer Instruction* pedagogy which is effective regardless of the modality used by students to report their answer.

The positive effect of proficiency on effectiveness

Since the *Peer Instruction* approach was developed at Harvard for Harvard students, one is pushed to question whether the effectiveness of the approach depends on the proficiency of the student. This study therefore compared the learning gains of students differing in proficiency (as measured by the FCI) before instruction. Results show that higher proficiency students had greater conceptual gains ($g=0.672$) than lower proficiency students ($g=0.387$) and that this difference was highly significant ($p<00001$). In the control section, a similar difference in conceptual learning between proficiency groups was found ($g=0.383$ vs $g=0.264$) present but this difference was found to be non-significant ($p=0.337$). This is an interesting result given previous findings that have shown the normalized gain 'g' to be independent of the pre-test score (Hake, 1998). Constructivism however, would predict that students with more prior knowledge learn more since new knowledge is constructed from prior knowledge (Cobb, 1994; Piaget, 1973, 1977, 1978; Vygotsky, 1962, 1978). If higher proficiency students perform sizeably better, then should *Peer Instruction* be used only with high proficiency students?

In fact the data collected in this study shows that low proficiency students in the *Peer Instruction* group performed better than both the high and low proficiency students in the traditional instruction control group. Furthermore, low proficiency students in the *Peer Instruction* group showed a statistical tendency (p=0.07) towards performing better than low proficiency students in the control section. This lack of outright statistical significance is probably due to the small number (n=9) of low proficiency students in the control section and that larger sample sizes may have provided sufficient statistical power to detect significant differences. At the very least, these results show that low proficiency students are not harmed by *Peer Instruction.* Therefore, although *Peer Instruction* works significantly better for high proficiency students its use with lower proficiency students remains commendable.

Student concept confidences

Much data concerning student confidences in physics concepts was gathered in this study. Major findings include the significant increase in concept-confidence after instruction (see table 4.5). Students in all groups increased in average concept-confidence after instruction and no significant differences for these increases were found between groups. Differences in confidences for correct or incorrect answers were sought to determine whether the average increase in confidence was due to an increase in correct or incorrect concepts. As expected, concept-confidences in correct answers increased significantly in all groups (see table 4.6). No significant difference in the increase in correct answer confidence was found between groups. Interestingly, all groups increased in incorrect concept confidence. Furthermore, this increase was statistically significant (p=0.011) in the clicker section. Why do students' confidence in wrong answers increase?

One may have expected a decrease in wrong answers confidence. Yet, recall that the nature of the FCI is to present students with situations where misconceptions seem as plausible as correct concepts. Since all students gain in confidence after instruction, and that misconceptions may still seem as plausible as correct concepts, on may explain why confidence in misconceptions increase after instruction. Increased wrong answer confidence may simply indicate that students are generally more confident in physics concepts after instruction: regardless of whether they are correct or not. Furthermore, since less wrong concepts exist after instruction, the misconceptions remaining after instruction are possibly those initially held with higher confidence. That is, suppose that initially 15 misconceptions were held. Suppose that 5 of these were held strongly and 10 of these were held moderately. After instruction it is possible that the moderately held misconceptions were changed while the strongly held misconceptions were not (i.e. only the 5 strongly held misconceptions remain). Since these misconceptions are profound, the confidence expressed in them remains strong. Thus it appears that the confidence in incorrect answers (now only 5 remaining) is stronger than initially (where the 5 strongly held misconceptions cohabitated with 10 other weaker held misconceptions). Therefore, since only stronger misconceptions remain, the average wrong answer confidence appears to have increased.

Using clickers in the classroom

Data from ConcepTest given in class were collected to give instructors interested in Peer Instruction an idea of the number of ConcepTest questions to give, the average rate of increases to expect after instruction as well as the expected rates of initially low and initially high response rates.

From reading Mazur's (1997) *Peer Instruction* book, I had expected great increases in correct answer rates after peer discussion. The average increase in correct answer rates observed was of 10.7% which is relatively modest. Yet, the conceptual learning gains obtained in this study (g=0.49 for clickers; g=0.52 for flashcards) are very similar to the conceptual learning gains (g=0.48) initially reported by Mazur (1997) after his first implementation. The remaining question is how do students increase in conceptual knowledge if so little gain is attributed to peer discussion?

This first possibility is the change in focus from algorithmic problem solving to conceptual physics. That is, in a traditional physics course, the computational aspect seems to dominate and students associate physics with formulas. Solving a physics problem becomes hunting for the correct formula. In *Peer Instruction,* the focus is set on basic concepts. To solve a problem one must first determine which concepts apply, sort out which equations translate this concept in mathematical language and then work towards a solution. Therefore, the entire format of the course enables conceptual change at least as much as student discussions do.

The second possible reason is conceptual change due to cognitive conflict. Indeed, when presented with a conceptual question in class, students must commit themselves to choosing an answer. This amounts to clarifying what one's preconception is and acknowledging it. Students often display great joy when their choice is correct. On the other hand, when a choice made is incorrect, a cognitive conflict is triggered which shifts the way a student conceptualizes the content. Those choosing wrong answers learn from their mistakes by having their acknowledged misconception explained. Therefore, part of the effectiveness of *Peer Instruction* resides in the peer discussion but another part (at least equally important) resides in the instructor's explanation of misconceptions.

Chapter 6

Summary and Conclusion

Peer Instruction is an effective pedagogical approach which must be widely disseminated and encouraged. Its approach is straight forward and simple enough to enable systemic change in relatively little time. This approach was developed and widely tested in physics as it was in this study. However, the *Peer Instruction* methodology proposed in this study focuses on student conceptual learning and is therefore not restricted to physics. The shift towards conceptual change in physics was brought about by the creation of the Force Concept Inventory. This has sparked researchers to create conceptual inventories in other science disciplines such as Astronomy (Sadler, 1998), Engineering (Krause, Decker, Niska *et al.,* 2002; Evans *et al*, 2002), Chemistry (Mulford & Robinson, 2002), Statistics (Stone, Allen, Rhoads, *et al.,* 2003) and others are currently being developed such as in Biology (Klymkowsky, Garvin-Doxas, & Zeilik, 2003). Currently, in class ConcepTest for chemistry and biology courses are available online (http://galileo.harvard.edu/) through the Harvard Project Galileo website and *Peer Instruction* is increasingly being adopted in a number of fields such as computer science (Lopez-Herrejon & Schulman, 2004), geosciences (Grear & Heaney, 2004; Owens *et al.,* 2004), chemistry (Kovac, 1999), biology (Brewer, 2003) and physiology (Paschal, 2002; Rao & Dicarlo, 2000).

This study shows the feasibility and effectiveness of *Peer Instruction* in Cegep contexts. Significant increases in conceptual learning were found and no difference in traditional problem solving skills were observed although *Peer Instruction* students had less class time devoted to problem solving activities. This study also found that clickers did not add significantly to students' learning. That is, although clickers have many advantages, their use does not increase the effectiveness of the *Peer Instruction* approach. The conclusion is that the technology is not the pedagogy and clickers should not be seen as a *sine qua non* condition to using *Peer Instruction*. The major findings of this study are summarized in point form below.

Summary of findings

- Peer Instruction (PI) can be implemented in Cegep
- One can expect PI to be welcomed by administrators, colleagues and students.
- The modifications required to course structure are:
    - **Feasible**: No radical change required. Greater focus on basic concept
    - **Profound**: requires one to rethink content and instruction
    - **Can require an initial time investment**: if one chooses to organize entire courses on PowerPoint. However, the preparation time required for subsequent presentation of the same content is greatly reduced.
- PI is ***more effective*** than traditional instruction in enabling ***conceptual learning***
- PI is ***as effective*** as traditional instruction in developing ***problem solving*** skills
- The effectiveness of PI is independent of the mode used to report answers in class
    - That is, clickers **do not** enable more learning than flashcards
- Higher proficiency PI students perform better than lower proficiency PI students
    - However, low proficiency PI students perform better than low proficiency traditional instruction students
- Students' average confidences in concepts increase after instruction
    - Concept confidence in correct answer significantly increases
    - Concept-confidence in wrong answers increases (not always significantly)
- A sizeable proportion (≈1/5) of in-class ConcepTests are poorly (<35%) answered
- A sizeable proportion (≈1/4) of in-class concept tests are well (>80%) answered
- ConcepTest given in class do not have large increases after peer discussion
    - Great conceptual gains can be expected although small changes are seen after peer discussion.

Conclusion

As stated in the introduction many science instructors teach today the way science was taught 100 years ago (Beichner *et al.*, 1999). Yet, the *Peer Instruction* approach is gradually changing the way instructors and students conceive instruction. Its methodology requires very little changes from traditional lecturing besides an extended focus on basic concepts. Its approach does not conflict with current institutional constraints as it is well received by administrators, teaching colleagues and students. By focusing on basic concepts it has taken away the perception that science (physics specifically) is about finding formulas. It has integrated Simon's (1996) notion that "*the meaning of "*knowing*" has shifted from being able to remember to being able to find and use*" by pushing students to find and use the basic concepts instead of remembering which formulas to use. Although its use of technology does was not found to add to students' learning, it integrates the current culture looking for newer forms of technology applications in the classroom. *Peer Instruction* is thus a choice pedagogical approach that must be warmly welcomed into our Cegeps and universities.

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ANNEXE – 1

Consent and Confidentiality Form

Implementing Peer Instruction in Cegep
c/o Department of Physics, John Abbott College
Nathaniel Lasry Project Coordinator

Consent and Confidentiality Agreement

I agree to participate in the "*Implementing Peer Instruction in Cegep*" research project with the understanding that all information I provide will be held in confidence and that all reports and publications will preserve the anonymity of individual respondents.

My participation will consist of my attendance and completion of this course. I agree to the researcher obtaining from John Abbott College my grades in my science courses on the understanding that the researcher will respect the confidentiality of this information, and not disclose my grades to any other party.

I understand that I may decline to answer any question, and may withdraw at any time from participation in this study. If I were to withdraw in the first 2 weeks of the semester, appropriate steps will be taken to have me transferred in another section will be taken. If I decide to withdraw after this date, all the data concerning me will be excluded of the study.

Questions or concerns about the research may be addressed to Nathaniel Lasry (Physics department John Abbott College) or to the John Abbott College Research and Development Committee, Johanne Houle, Chair.

Participant ____________________ Signature ______________________
Print name

Researcher ____________________ Signature ______________________
Print name

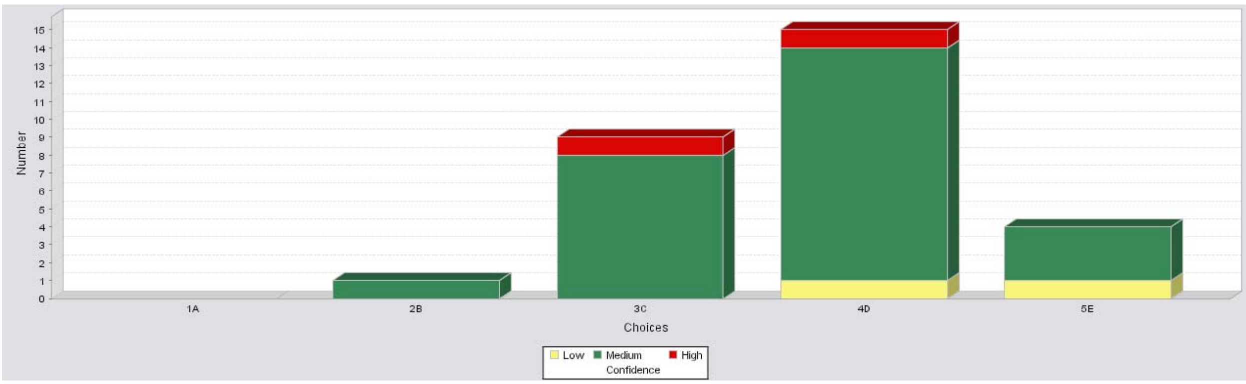
DATE ________________

ANNEXE – 2

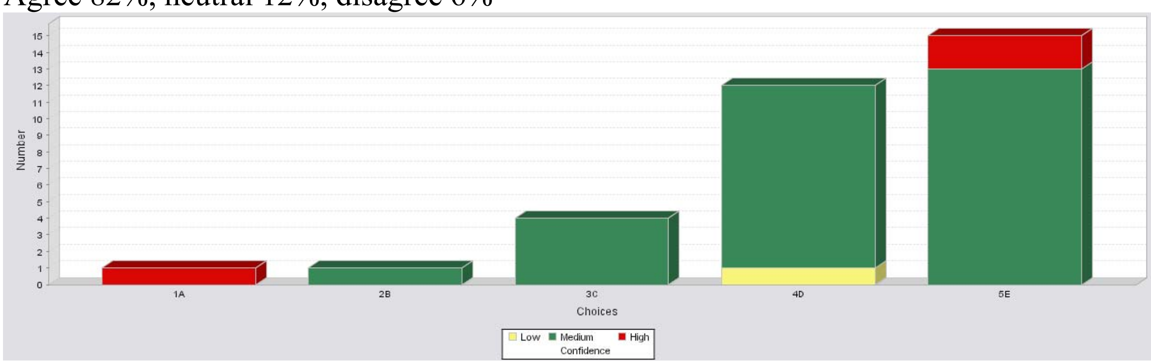
Student Appreciation Survey

Clicker Survey

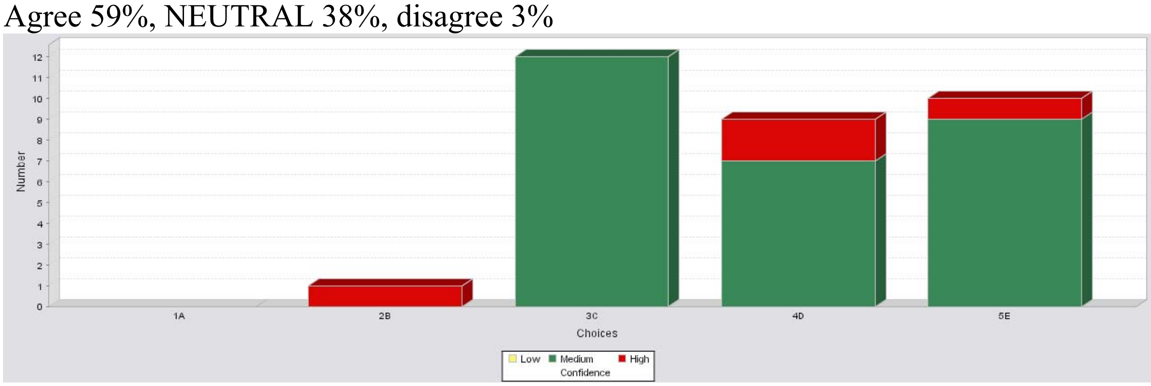
Q1 (n=29)
Peer Inst helped me recognize what I misunderstood
Agree 66%, neutral 31%, disagree 3%



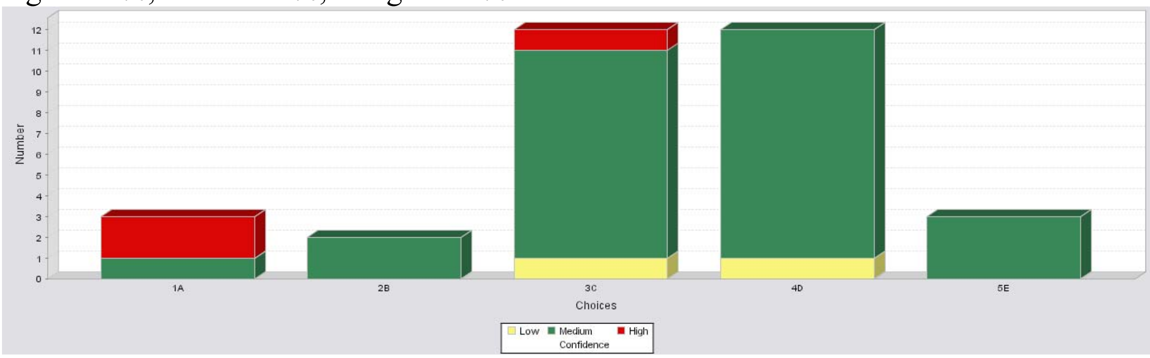
Q2 (n=33)
PI showed me that other students had misconceptions similar to mine
Agree 82%, neutral 12%, disagree 6%



Q3 (n= 32)
I actively discuss problems with my classmates
Agree 59%, NEUTRAL 38%, disagree 3%

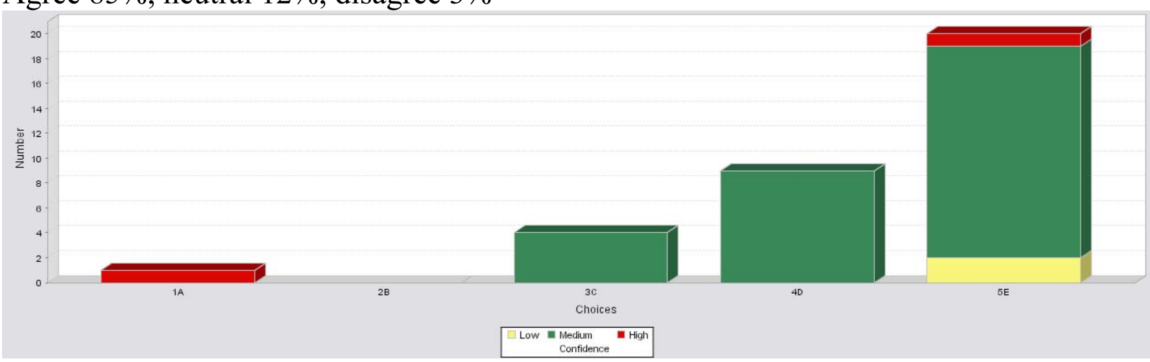


Q4 (n=32)
Convincing other students helps me to understand concepts
Agree 47%, neutral 38%, disagree 15%

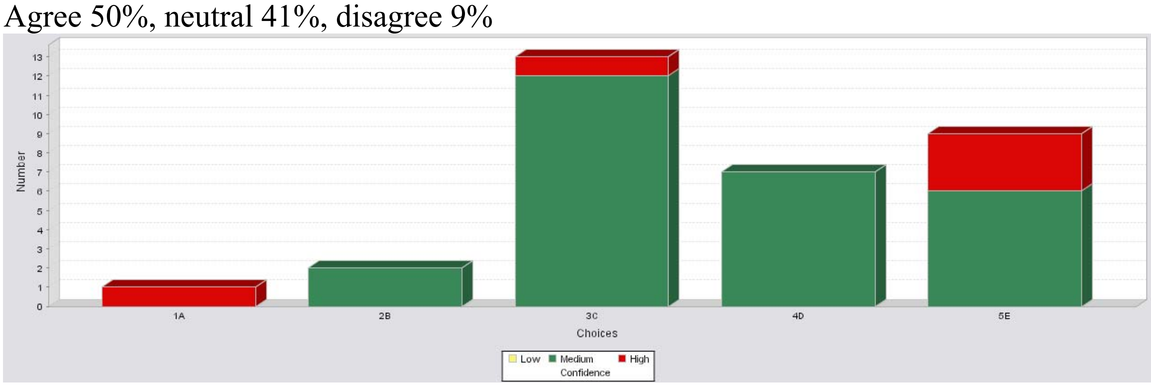


Q5 (n= 34)
The mini-lectures help to clarify the concept for me

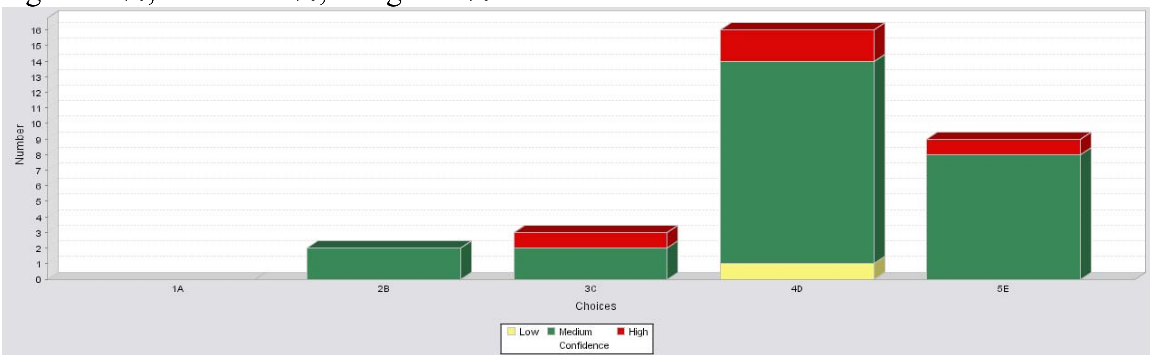
Agree 85%, neutral 12%, disagree 3%



Q6 (n= 32)
Peer Instruction helps to learn better then traditional lectures
Agree 50%, neutral 41%, disagree 9%

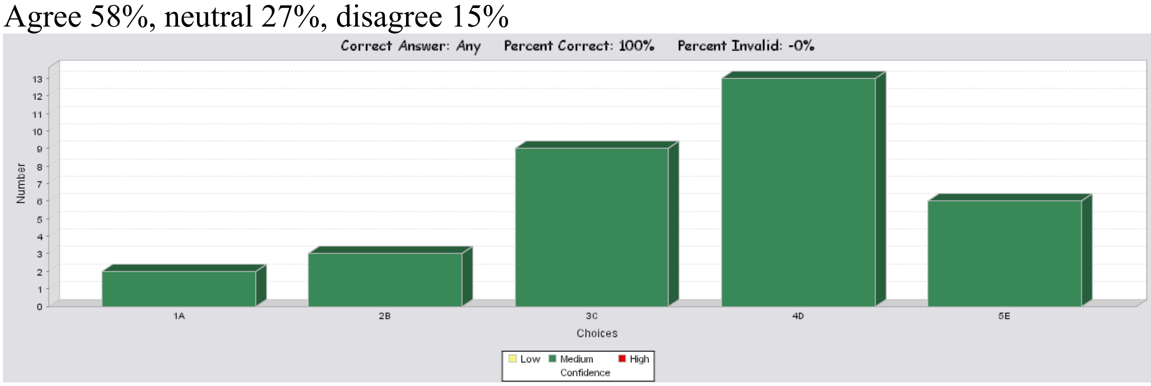


Q7 (n= 30)
If I had the choice between a PI course and a traditional course I would choose PI
Agree 83%, neutral 10%, disagree 7%

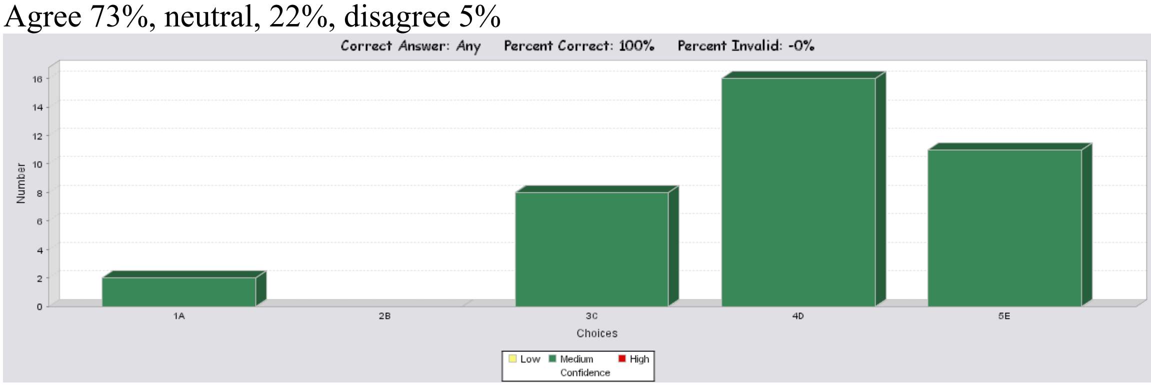


Flashcard SURVEY

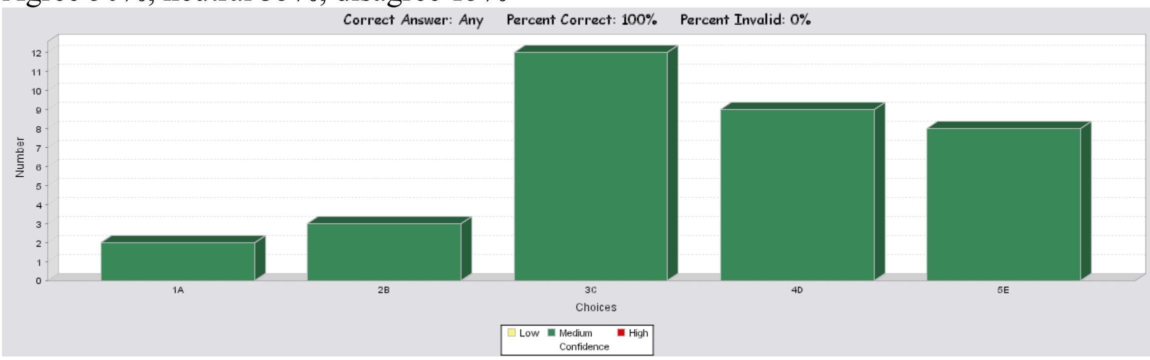
Q1 (n=33)
Peer Inst helped me recognize what I misunderstood
Agree 58%, neutral 27%, disagree 15%



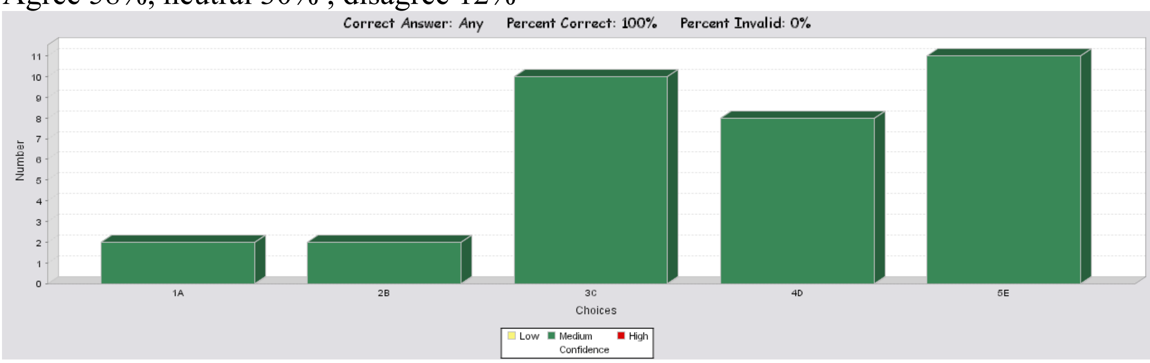
Q2 (n=37)
PI showed me that other students had misconceptions similar to mine
Agree 73%, neutral, 22%, disagree 5%



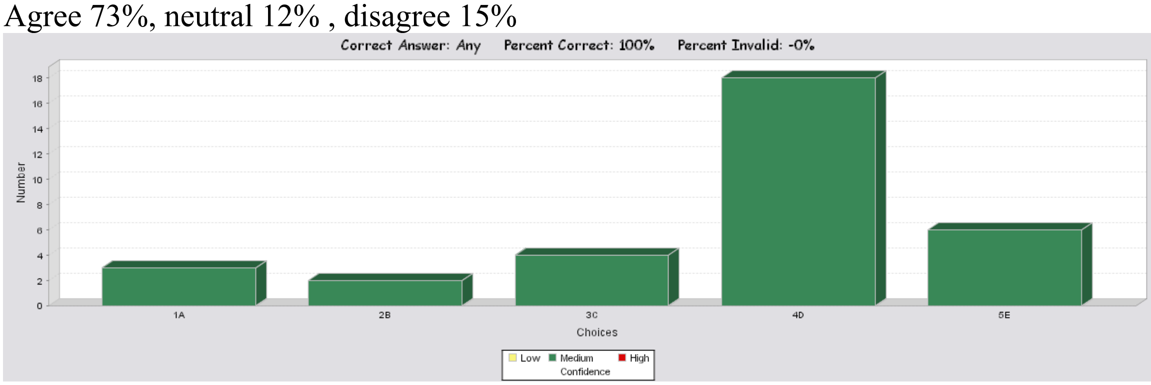
Q3 (n= 34)
I actively discuss problems with my classmates
Agree 50%, neutral 35%, disagree 15%



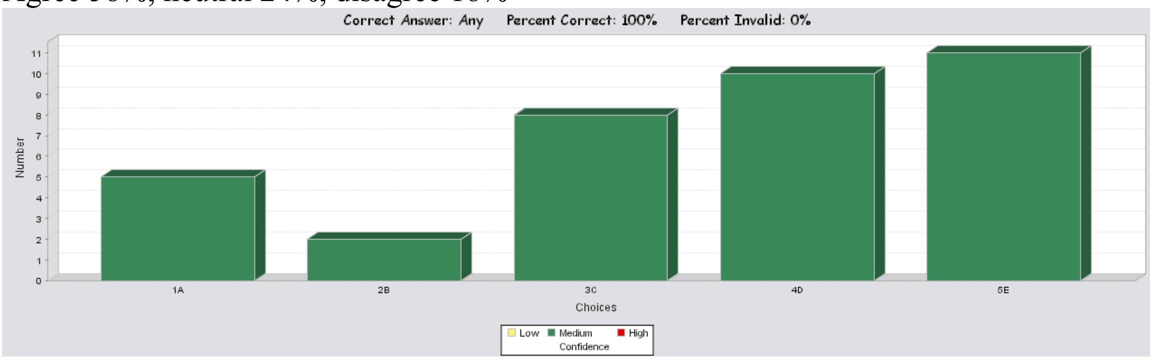
Q4 (n=33)
Convincing other students helps me to understand concepts
Agree 58%, neutral 30% , disagree 12%



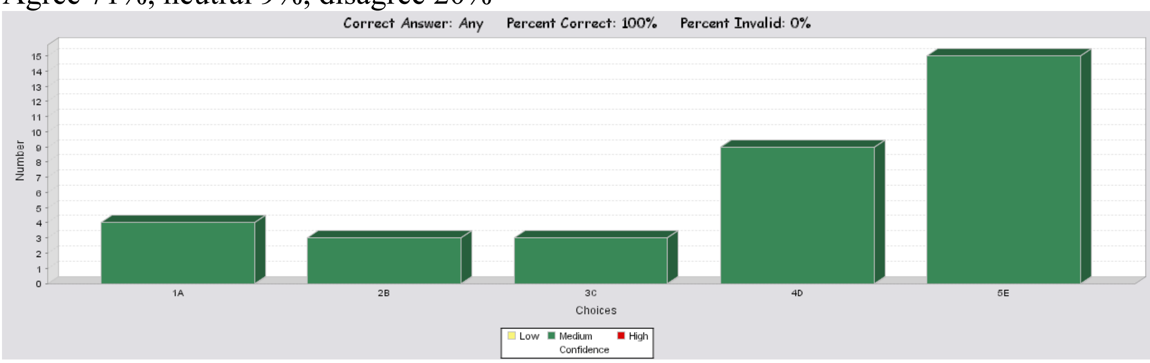
Q5 (n= 33)
The mini-lectures help to clarify the concept for me
Agree 73%, neutral 12% , disagree 15%



Q6 (n= 36)
Peer Instruction helps to learn better then traditional lectures
Agree 58%, neutral 24%, disagree 18%



Q7 (n= 34)
If I had the choice between a PI course and a traditional course I would choose PI
Agree 71%, neutral 9%, disagree 20%



Q8 (n=36)
If I had clickers instead of flash cards I would have participated more
Agree 61%, neutral 11%, disagree 28%.