

UNIVERSITÉ DE SHERBROOKE

**Les Clickers par Opposition à la Main Levée dans la Salle de Classe de  
Physique au Niveau Collégial: les Clickers Font-ils une Différence?**

**CLICKERS VERSUS HAND-RAISING IN THE PHYSICS COLLEGE  
CLASSROOM: DO CLICKERS MAKE A DIFFERENCE?**

par

Joanne L. Kettner

Essai présenté à la Faculté d'éducation

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## SUMMARY

Students who are actively involved in the learning process tend to develop deeper knowledge than those in traditional lecture classrooms (Beatty, 2007; Crouch & Mazur, 2001; Hake, 1998; Richardson, 2003). An instructional strategy that promotes active involvement is Peer Instruction. This strategy encourages student engagement by asking them to respond to conceptual multiple-choice questions intermittently throughout the lecture. These questions can be responded to by using an electronic hand-held device commonly known as a clicker that enables students' responses to be displayed on a screen. When clickers are not available, a show of hands or other means can be used. The literature suggests that the impact on student learning is the same, whether the teacher uses clickers or simply asks students to raise their hand or use flashcards when responding to the questions (Lasry, 2007). This critical analysis argues that using clickers to respond to these in-class conceptual multiple-choice questions as opposed to using a show of hands leads to deeper conceptual understanding, better performance on tests, and greater overall enjoyment during class.

Interest in this phenomenon began when the author noted that test grades for a CEGEP physics class taught with clickers (fall 2012) were higher than when compared to test grades for classes taught where students raised their hands to the same multiple-choice questions as the clicker class (test 1 – fall 2010 term, test 2 – fall 2011 term, test 3 – winter 2011 term). In addition to comparing test grades, students in the clicker class responded to a questionnaire, giving feedback about using clickers. They reported that clickers create a risk-free learning environment, increase peer interaction, increase motivation, and help students undergo conceptual change. The literature on constructivism, peer instruction, deep learning, conceptual change, immediate feedback, and autonomy are used to explain these observations and student responses.

This critical analysis concludes that clickers are more beneficial than hand-raising in helping students acquire greater conceptual understanding and problem solving skills in CEGEP physics.

## RÉSUMÉ

Les étudiants qui sont activement impliqués dans le processus d'apprentissage ont tendance à développer des connaissances plus approfondies que lors de cours traditionnels (Beatty, 2007; Crouch & Mazur, 2001; Hake, 1998; Richardson, 2003). Une stratégie d'enseignement qui favorise la participation active est l'apprentissage par les pairs. Cette stratégie d'enseignement encourage l'engagement des élèves en leur demandant de répondre à des questions à choix multiples conceptuelles à plusieurs reprises durant le déroulement du cours. Ces questions peuvent être répondues à l'aide d'un appareil portatif électronique (un « clicker ») qui permet d'afficher de façon anonyme les réponses des élèves sur un écran. Si les clickers ne sont pas disponibles, les étudiants peuvent aussi répondre aux questions en levant la main. La littérature suggère que la méthode utilisée n'a pas d'impact sur l'apprentissage des élèves, que l'enseignant utilise des clickers, des flashcards ou qu'il demande simplement aux élèves de lever la main pour répondre aux questions (Lasry, 2007). Cette analyse critique fait valoir que l'utilisation de clickers pour répondre à ces questions à choix multiples conceptuelles en classe, plutôt que de faire lever la main aux étudiants, résulte en une compréhension conceptuelle plus approfondie, une meilleure performance aux examens et plus de plaisir pendant les cours.

L'auteure s'est intéressée à ce phénomène lorsqu'elle a remarqué que les notes obtenues aux examens dans un cours de physique, niveau cégep, enseigné à l'aide de clickers (automne 2012) étaient plus élevées que celles obtenues pour le même cours, mais enseigné en demandant aux étudiants de lever la main pour répondre aux mêmes questions à choix multiples (test 1 – session d'automne 2010, test 2 – session d'automne 2011, test 3 – session d'hiver 2011). En plus de comparer les résultats d'examen, les élèves ayant utilisé les clickers ont répondu à un questionnaire pour donner leurs commentaires sur l'utilisation des clickers. Les élèves ont remarqué que les clickers favorisent un environnement d'apprentissage sans risque, augmentent l'interaction entre les pairs, augmentent la motivation d'apprentissage et aident les élèves à subir les changements conceptuels. Une revue de littérature sur le constructivisme, l'apprentissage par les pairs, l'apprentissage en profondeur, le changement conceptuel, la rétroaction immédiate et l'autonomie est utilisée pour expliquer les observations de l'auteure et les réponses des élèves.

La conclusion de cette analyse critique est que l'utilisation de clickers apporte plus de bénéfices que la simple levée de mains pour aider les élèves à atteindre une meilleure compréhension conceptuelle et des compétences en résolution de problèmes en physique au cégep.

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## INTRODUCTION

Getting students actively engaged in their own learning is a challenge facing teachers in all disciplines. This is particularly difficult in college level physics classrooms since students find physics concepts difficult to grasp and often try to learn how to solve problems by rote as opposed to actually acquiring a deep understanding of the material. Physics teachers have realized that many students approach physics in this way and have been trying to find new teaching methods to help students acquire greater conceptual understanding and more thorough approaches to solving problems.

One method that has become popular in academic environments is Peer Instruction (PI). PI, as introduced by Harvard physics professor Eric Mazur, is a teaching technique geared to get students actively involved in the learning process by asking students conceptual multiple-choice questions during the class period (Mazur, 1997). Students are given the chance to respond to the question right away using a clicker. A clicker is a hand held electronic device that allows students to press a button (A, B, C, D, or E) that corresponds to the answer to a multiple-choice question. Once the students have responded, their results are displayed anonymously on a screen showing how well the students, as a group, understood the topic in question. Depending on the results students are given the opportunity to discuss their responses, and convince their peers that their answer is correct or try to be convinced that another answer is correct. They are then asked to revote. The act of thinking about, talking about and committing to a response gets the students involved and more motivated to pay attention during class because they know that they will be asked to justify their responses and because they are interested to find out if their reasoning and responses are correct.

The literature suggests (Lasry, 2007) that having students raise their hands or use flash cards instead of using clickers to respond to these conceptual multiple-choice questions is equally beneficial for students. Based on my students CEGEP physics test results, my students perceptions about using clickers and the literature on this topic, I believe that when students use clickers over a show of hands their conceptual understanding of physics and performance on tests improves. This critical analysis explains how using clickers differs from hand-raising and how this difference impacts on student learning.

## **CHAPTER 1: PROBLEM STATEMENT: FOSTERING CONCEPTUAL UNDERSTANDING IN PHYSICS**

Educational research continues to show that students learn better when active learning techniques based on constructivist theories of learning are used. These techniques require students to be mentally active during lectures such that they consciously question their understanding, a mental process which can lead to deep learning (Beatty, 2007; Cannon & Knapper, 2011; Crouch & Mazur, 2001; Dawson, Meadows & Haffie, 2010; Hake, 1998; Preszler, Dawe, Shuster, C. B., & Shuster, M., 2007; Richardson, 2003).

Research in physics (Crouch & Mazur, 2001; Hake, 1998) suggests that students who are taught in a traditional lecture format, often do not comprehend the material at a deep level. In an effort to change this common outcome, Eric Mazur, a Harvard physics professor, designed an instructional strategy called Peer Instruction (PI) which is an active learning technique geared to increase students' understanding of physics concepts, their long term memory, and their performance on tests (Mazur, 1997). An important step in this teaching technique includes having students respond to multiple-choice conceptual physics questions, while the lecture is in progress, by using clickers (electronic handheld devices). Once the students respond, their results are anonymously displayed on a screen, allowing the teacher and students to see how well the class understands the concept. Depending on these results the teacher can adapt the lecture to the students' needs. When the majority of the class gives the correct response, the teacher can give a brief explanation and move on to the next topic. If a large percentage of the group gives an incorrect answer, the teacher gives students the chance to discuss their answers with their peers and change their response if necessary. Depending on the results of the second response, the teacher determines what additional explanations and/or activities are needed to increase student understanding.

PI is not dependent on the use of clickers. According to Lasry (2007) students can raise their hands or use flashcards and the results will be the same; comprehension will increase. However, in my own practice, after using each approach, hand-raising and clickers, I have concluded that using clickers increases learning as measured on class tests.

This critical analysis examines the components of a particular pedagogical approach (the constructivist method of PI) and relates it to a conceptual framework in order to explain why PI, used in a specific way, is an effective method of fostering conceptual understanding in the learning of physics. It specifically examines why students who are asked to respond to conceptual questions in physics using clickers seem to develop a deeper understanding of the subject than students who do not use clickers. This research question stems from the results of an informal analysis completed in the Winter of 2013. Test results (problem solving and conceptual questions) for CEGEP physics students in the fall of 2012 who used clickers to respond to in-class conceptual multiple-choice questions were compared to the test results of students from previous semesters who were asked to raise their hands when responding to the same in-class questions. Their average test grades were higher than students who did not use clickers in their physics classes in the winter of 2011, the fall of 2010, and significantly higher than the non-clicker class of the fall 2011 term. A critical analysis of the literature was carried out with the aim of explaining the phenomenon witnessed in my practice. Since my colleagues in the physics department at Champlain College and myself believe that students learn better when we apply instructional strategies and learning activities that demand the intellectual engagement of the learner in their own learning process, we are always striving to find new effective active learning techniques for our students. Therefore, if a critical analysis of the literature can explain the significant increase in student performance was found, then other members of my department may start using clickers, leading to greater conceptual understanding in physics for many CEGEP students.

## 1 CONCEPTUAL FRAMEWORK

The conceptual framework for this Masters project is based on constructivism. The most salient tenet of constructivism is the centrality of the learner in making meaning by active engagement individually and/or socially (Cobb & Yackel, 1996; Moshman, 1982; Shuell, 1986). In this learning centred perspective, the measure of effective learning is not just a quantitative gain (i.e., knowing more) but a qualitative change (i.e., knowing differently) as the learner accommodates and assimilates new knowledge within their existing knowledge. Resnick (1989), quoted in Richardson (2003) describes this; “The general sense of constructivism is that it is a theory of learning or meaning-making, that individuals create their own new understandings on the basis of an interaction between what they already know and believe and ideas and knowledge with which they come into contact” (pp. 259 – 260). As put forward by Richardson (2003), constructivist pedagogy consists of a student-centred learning environment where student engagement is facilitated by the teacher in a way that leads to a deeper understanding of the content being taught. In a constructivist environment students are encouraged to challenge the ideas of others and to have their own ideas challenged in a way that leads to the formulation of new knowledge as well as knowing about concepts in a different way. Knowing differently requires the acquisition and application of higher order cognitive processes and transferable skills such as problem solving, analytical thinking, and reasoning.

In order for students to acquire new knowledge and to know differently they must experience a conceptual change. “In conceptual change, an existing conception is fundamentally changed or even replaced, and becomes the conceptual framework that students use to solve problems, explain phenomena, and function in their world” (Davis, 2001, p. 2). In physics, students often have misconceptions about certain topics and are resistant to changing these beliefs. The process of clarifying these misconceptions begins by making students aware of them. Once this has been accomplished students are led to question these misconceptions, individually or



collectively, leading to the realization that there is a flaw in the logic of these beliefs. After accepting this, they will then be able to acquire a new understanding about the concept in question. It is important for students to be placed in a situation where they come to the conclusion that their misconceptions do not make sense. If they are just told this, it is unlikely that conceptual change will occur; the students must become dissatisfied with their current conception as this will make them want to find a new and improved explanation of the concept (Davis, 2001; Hewson, 1992; Özdemir & Clark, 2007). Therefore it is important for teachers to create a learning environment that enables students to come to these conclusions so that they can develop an accurate and deeper understanding of the concepts. This will only happen if the students are given the opportunity to be actively involved in the learning process, as Davis (2001) describes, “Teaching for conceptual change requires a constructivist approach in which learners take an active role in reorganizing their knowledge” (p. 5).

Deep learners seek to understand the material presented by making links between the new material and their prior knowledge and experiences. They attempt to use what they already know to formulate a more complete understanding about the new material, and they internalize their learning and create meaning (Ramsden, 2003). Deep learners have a desire to find meaning in the material they are studying. Conceptual change may occur in the learner once this meaning has been acquired (Entwistle, 2000). Surface learners, on the other hand, are more concerned with getting the task done than in understanding the material. They focus on memorization, they fail to make links between new material and prior knowledge, and they are unable to relate content to their everyday lives (Entwistle, 2000; Ramsden, 2003). Entwistle (2000) describes different conceptions of teaching; *teacher focused content oriented* and *student focused learner oriented*. Entwistle (2000) concludes that the student focused learning oriented conception of teaching facilitates understanding and encourages conceptual change thus leading to a deep and thorough understanding of the concepts being taught. The teacher focused content oriented conception of teaching, on the other hand, is more concerned with

students reproducing and transmitting factual knowledge which results in students having a surface understanding of the material. The constructivist view of learning seeks to create deep learners who acquire conceptual change by being actively engaged in what they are learning.

### 1.1 Peer Instruction

Eric Mazur, a Harvard physics professor, developed Peer Instruction (PI) in the early nineties after realizing that his students had mastered the skills required to solve physics problems because they had learned the problem solving steps but they did not have a deep understanding of the concepts of physics that they were using, that is, the concepts inherent in the problems (Mazur, 1997; Travis, 1994). This realization caused Mazur to redesign the format of his courses, moving away from traditional lecturing and towards PI as his new teaching method.

Mazur's teaching method of Peer Instruction is based on constructivist principles as it forces the learner to add to or reorganize or correct their current knowledge. In a PI classroom students are more actively involved in the learning process than in a classroom using a traditional lecture format. During class, the physics teacher gives a short description of a topic and then asks the students a conceptual question, called a concepTest, about this topic. After one or two minutes students submit their answer to the instructor using clickers or by raising their hands. They are then given an additional two to four minutes to discuss and debate their answer with peers. The instructor walks around the room listening to the discussions and asks questions to students who are not actively involved in the discussion. After debating, the students are asked to re-submit their response to the concepTest. Their answer may remain the same or change as a result of the interaction they had with their peer. The answer is explained to the class, in great detail, if a high percentage of students gave the wrong response and in less detail if many students gave the correct answer (Crouch & Mazur, 2001; Mazur, 1997). This method has gained wide popularity and is now being implemented not only in introductory physics classes

but also in nursing, communication, engineering, computer science, mathematics, chemistry, philosophy, biology, premedical education, business, economics, and psychology classes as well as being offered in elementary schools, high schools and at the undergraduate and graduate level (Caldwell, 2007).

When students learn in a PI classroom, they are forced to be actively involved and must think about the material that is being taught. Since the conceptTests are asked many times throughout the period, students are motivated to pay attention to the material as it is being explained because they know they will have to answer questions and justify their answers during class time. As pointed out by Beatty (2004), as soon as students choose an answer, they are more interested in the discussion that follows since they want to know if their answer is correct. Unlike the traditional classroom where students sit quietly at their desks copying notes from the board or screen, PI encourages the students to remain active during the period which in turn increases their understanding of the content. It also allows for deeper engagement; the discussions are immediate, the feedback is immediate, and the voting takes place twice.

## **CHAPTER 2: LITERATURE REVIEW**

Over the past few decades, studies have shown that when students are actively involved and engaged in the learning process (ie., a constructivist atmosphere) their conceptual understanding and problem solving skills in physics, and other disciplines, improve dramatically in contrast to when they are taught in a traditional lecture classroom (Crouch & Mazur, 2001; Hake, 1998; Lazry, Mazur & Watkins, 2008; Nicol & Boyle, 2003; Weiman & Perkins, 2005). When a student is encouraged to question and justify their understanding about a given topic, they are more likely to develop a deeper comprehension about the material being taught. If this questioning and justification is followed by instant feedback and an explanation by the teacher, then students are more likely to stay focused during class since they are keen to find out if their reasoning is correct. Also, when students are given the opportunity to become autonomous in their learning they will be more engaged in the learning process, perform better on tests, retain more information, and will be more interested in the course material (Black & Deci, 2000; Niemiec & Ryan, 2009; Reeve & Jang, 2006; Reeve, Jang, Carrell, Jeon, & Barch, 2004; Ryan & Powelson, 1991). This chapter examines how the implementation of different active learning immediate feedback techniques such as PI, class-wide discussions, clickers, and interactive computer simulations in university and college physics, psychology, mechanical engineering, and biology classrooms has led to an increase in students' conceptual understanding and problem-solving skills. It will also report on student feedback after using these active learning techniques, and examine the importance of teacher supported autonomy in the classroom, an aspect of the impact clickers have on learning.

An extensive study examining the effect of student-based learning techniques on the conceptual understanding of introductory physics students was performed at Harvard University (Crouch & Mazur, 2001) between 1990 and 2000. All students (121-246 students per class) in this study (those in PI classes and those in traditional lecture classes) took a Force Concept Inventory (FCI) test at the beginning and end of their physics course. This is a test that measures students' basic conceptual understanding of Newtonian physics and is designed to test students' conceptual knowledge before and after they have taken a physics course. The results of the study demonstrate a marked improvement in the FCI score in classes implementing PI when compared with those using traditional physics lectures, implying that when students are active in the learning process, and receive immediate feedback for their efforts, they gain a deeper understanding of the material and perform better on tests. In 1997, students in a PI-instructed calculus based physics class had an FCI average of 67% on the pre-test and an average of 92% on the post-test, while in 1993, students in a traditional lecture calculus based physics class had an average FCI pre-test score of 70% and an average post-test score of 86% (Crouch & Mazur, 2001). Similar results were shown for algebra based physics courses in 1999 and 2000. Another aspect that was examined in this study was the difference in problem solving skills in the two learning environments. Less emphasis was given to problem solving during class time with PI but the results indicate that despite this, students who are taught with PI were still better at problem solving than those taught through traditional lecturing. In 1991, PI students were given an identical final exam as the one given to students taught in a traditional lecture course in 1985. The average in the traditional class was 63% and it was 69% in the PI class. This was a statistically significant difference in the average grades between the two classes. The final part of this study examined how conceptTests increased students' physics comprehension. Crouch & Mazur (2001) analysed the results over the entire fall 1997 semester and found that when 35% to 70% of students initially gave the correct answer to a concepTest, there was a huge increase of students giving the correct answer to the question after the discussion period. They found that the majority of the students who changed their initial answers after the discussion period changed

from the wrong response to the correct one. Finally, no single student gave the correct answer before the discussion more than 80% of the time, showing that even the brightest students are challenged by conceptTests and have gaps in their fundamental knowledge of physics. These results suggest that getting students to explain their reason for choosing an answer to their peers leads to a deeper understanding of the material for these actively involved students.

A similar study to that of Mazur was carried out at John Abbott College, a Montreal CEGEP (Lazry et al., 2008). This study consisted of two PI classes and one traditional lecture class of approximately 40 students each. Each student in the study was given a FCI test before the classes began (both groups had similar results) and again after completion of the course. Their Hake's normalized gains, a measure of the average of the individualized student gains (Hake, 1998) were compared and the results showed that students in the PI groups made greater improvements than those in the traditional group, confirming that PI students acquire greater conceptual knowledge than non-PI students. The results were significant at the  $p < 0.01$  level (Hake, 1998 referenced in Lazry et al., 2008). The study also tested both groups on their problem-solving skills. All students in the study were given the same final exam, 90% of the final exam consisted of non-conceptual calculation-based problems. The PI groups had an average grade of 68% while the traditional groups scored an average of 63%. These results were statistically significant since they yielded a p-value less than 0.001. Lazry et al. (2008) concluded that these results imply that a good conceptual basis increases problem-solving skills even when less time is spent on solving problems during class-time. Caldwell (2007) and Mayor et al. (2009) also describe this benefit, increased performance on tests as well as increased comprehension, for students who were taught using clickers despite leaving less class-time to cover content. The third part of the study looked at how background knowledge affected student learning outcomes. The traditional classes were separated into two groups; those who performed above and below the median on the conceptual Newtonian Mechanics test written before classes began. The findings were that the students in the PI classes scored higher than those in

traditional classes for both situations, although those who had greater incoming knowledge improved by a larger amount ( $p < 0.001$ ) than those with lower incoming knowledge ( $p < 0.07$ ). There have been many other high schools, colleges, and universities that have done similar studies to those carried out at John Abbott College and Harvard University. All of these studies have led to the same results; students taught with PI methods perform better on their FCI post-test and display greater conceptual understanding and problem solving skills in introductory level physics courses than those in lecture based classrooms (Hake, 1998).

The University of California, Santa Barbara is another university that did a study similar to those by Crouch & Mazur (2001) and Lazry et al. (2008). In this study, Mayor et al. (2009) compared midterm and final grades for three college-level educational psychology university classes as opposed to college-level physics classes. The classes were taught in different semesters but were all taught by the same instructor who used identical lecture material, reading assignments, and exam questions. The first class, taught in 2005, was a control group. This group did not use clickers nor respond to multiple-choice questions during class (ie. a traditional lecture format). The second class, taught in 2006, was the clicker group. This group was asked two to four multiple choice questions during each class and used their clickers to answer these questions (ie. a PI format). The third class, taught in 2007, was the no-clicker group. This group was given the same multiple-choice questions as the clicker group but they were given these questions on a piece of paper at the end of the lecture (or a section of the lecture) and were asked to write down the correct response. The class then went through the questions together and students were asked to raise their hands for the answers they thought were correct and they were then asked to explain their reasoning for choosing these responses. They were then asked to grade their papers and return them to the teacher. Incoming SAT scores, the proportion of juniors and seniors, and the proportion of women were compared for the three classes. These comparisons confirmed that there were no significant differences between the groups. The average midterm and final exam grades were calculated for each class and the clicker group had a statistically higher

average (83.4%) than the other two groups (80.2% for the no-clicker group and 80.3% for the control group). These results imply that students who are actively involved in cognitive processing during learning exhibit better understanding and performance on tests. Mayor et al. (2009) believe this is due to the fact that students, who know they are going to be asked questions during class and that they will receive immediate feedback to these questions, pay more attention during class in preparation for the questions, mentally organize prior knowledge while they are answering the questions, and develop the skills required to determine how well they understand the material being covered due to receiving instant feedback.

PI is not the only useful active learning technique applied by teachers; class-wide discussions (CWD) have also shown to aid in the conceptual understanding of students. CWD is an approach similar to PI. With this teaching method, students start by discussing the answer to a conceptual question in groups (3-5 minutes) as opposed to coming up with an answer on their own initially as is done with PI. Once the groups have submitted their answer using clickers and viewed the responses from all the groups on a screen, at least one of the groups is asked to explain their answer to the class. Knowing that one group is going to have to justify their response in front of the class provides increased incentive for the students to work together to come up with a good explanation. Based on the response, the teacher then facilitates a class wide discussion and explains the correct response. At the University of Strathclyde in the UK, a study comparing PI to CWD in a class of 100 first year mechanical engineering students was performed (Nicol & Boyle, 2003). The students were taught with both methods (PI and CWD) during their twelve week term. In the fifth week of the term, immediately after having been taught with both methods, the students responded to a critical incident questionnaire describing their reactions to being involved in an interactive classroom setting. In addition to responding to this questionnaire, the students were interviewed twice during the term about their perception about the two techniques used and their motivation. They were interviewed in groups of six during the seventh week while CWD was being used and during the tenth week while PI was being used. After the students had been



interviewed, a 36 statement survey was created based on their responses and was used to validate the interview results.

The results of this study showed that students felt they benefitted from both interactive teaching methods but had an overall preference for PI. They believed both methods led to an increase in their conceptual understanding of the course material since each technique gave them the chance to take part in peer discussions, allowed them to think about the material they had just been taught, and gave them the opportunity to see their peers' responses to the questions. They also felt that it was less intimidating and sometimes easier to learn from peers as opposed to teachers. The main reason students preferred PI over CWD was because they liked having time to think about the question on their own before discussing with peers. They felt that this gave them a chance to justify their response which then gave them more confidence when they were trying to convince their group that their response was correct. Students felt more uncomfortable with CWD because they did not like being put on the spot to explain their answer to the whole class. They also felt that hearing other groups' responses sometimes led to confusion when the responses were incorrect and this affected their overall understanding of the topic. Martyn (2007) also did a study comparing class discussions to clickers and found similar results; the students preferred using clickers to class discussions. These students (Martyn, 2007) felt that clickers improved student-student and student-teacher interactions, helped students understand the course material, and gave the students a greater sense of belonging in the classroom.

Barnett (2006), like Nicol & Boyle (2003) and Martyn (2007), performed a study that focused on students' perceptions about their learning in university classes. Barnett's (2006) study was carried out at the University of Western Ontario for three introductory science courses (Biology 022, Biology 023, and Physics 028) that were using clickers as a new teaching tool during lectures. The total number of students taking these courses was between 1200 and 1400 (some students were taking one of the biology courses as well as the physics course). The professors used clickers

during class and asked the students to take part in an anonymous open-ended online survey about the benefits and disadvantages associated with using clickers.

560 students responded to the survey and their responses were then categorized and coded. Overall, the students reported positive feedback about using clickers during class time. The most popular reason reported for liking clickers (36.2%) was the instant feedback about how well the students understood the material they had just learned. The second and third most popular reasons were, being able to interact with peers during lectures about the course content (22.9%) and being able to see how well students understood the material in comparison to their peers (20.7%). These two reasons were also cited by the engineering students at the University of Strathclyde (Nicol & Boyle, 2003). Another reason biology and physics students at the University of Western Ontario (Barnett, 2006) enjoyed using clickers was that it got them more involved during class (15.4%). There was some negative feedback reported by these students but the positive feedback dominated: 38.5% of the students said they had no negative feedback about using clickers, 24.0% discussed technological problems as a negative impact of clickers (this mostly included having trouble while registering the clickers), and 15.2% said that the technology was not used well during class.

Another study (Preszler et al., 2007) that examined students' attitudes about using clickers obtained positive feedback. A total of 550 students from six different biology courses (freshman to senior) at New Mexico State University responded to an online questionnaire at the end of term about using clickers during the term. The most popular reason (81%) that students enjoyed using clickers in class was that it made them more interested in the course. They also found that using clickers motivated them to attend classes (71%) and they felt that clickers helped them understand the course material (70%). Beatty (2004) also discusses reasons that students enjoy using clickers during class; they found that clickers helped them stay engaged in class, they found that listening to their peers explanations about a given topic helped them understand the material, they appreciated the instant feedback,

especially being able to see how well the group understood the material, and they found that clickers made classes more fun.

In addition to obtaining student feedback about clickers, Preszler et al.'s (2007) study also compared students' performance on exams based on the number of clicker questions they had been asked during a typical lecture. The frequency of clicker questions per class was categorized as low, medium, and high. For all six biology courses the students in the high frequency class obtained the highest grades on their exams, next were those in the medium frequency classes, and finally those in the low frequency classes. These results imply that by being more actively involved in the learning process by responding to and discussing clicker questions as well as receiving more feedback about their comprehension with the increased number of clicker questions, students are acquiring deeper learning and are performing better on tests. Majerich, Stull, Varnum, Gilles & Ducette (2011) also came to this conclusion after comparing final exam scores of university physics students in clicker classes versus non-clicker classes.

When students use clickers with PI they are actively involved in the learning process and are provided with immediate feedback on how well they understand the course material. The advantages of receiving immediate feedback on multiple-choice test questions was examined in the studies performed by Dihoff, Brosvic & Epstein (2004) and Epstein M. L., Lazarus, Calvano, Matthews, Hendel, Epstein, B. B., & Brosvic (2002). In these studies, the Immediate Feedback Assessment Technique (IFAT) approach was used on undergraduate university students. This approach is geared to get students actively involved when responding to multiple-choice test questions. When students answer these test questions, they scrape off a bit of paper that corresponds to one response (ie., A, B, C, D). If the response is correct, a star or some other symbol is displayed under the paper. If the response is incorrect, there is no symbol and the students are given the opportunity to think about and change their response. This testing approach gives students immediate feedback on their work and allows them to figure out the correct response during the test period as opposed

to not knowing if their responses are correct or not until receiving their graded tests days later, as is often the case with multiple-choice tests. “It [IFAT] retains the benefits of being an engaging medium that supports learning by providing reinforcing feedback for correct responses and corrective feedback for incorrect responses while involving the participant in a discovery process” (Epstein et al., 2002, p. 199). In both studies by Dihoff et al. (2004) and Epstein et al. (2002), all students were given two tests. On the first test, they responded using either IFAT (immediate feedback and had the opportunity to change their answers) or Scantron answer sheets (multiple choice answer sheets that do not give any feedback and do not allow students to change their answers). On the second test, they were tested on the same material as the first test. The students who had responded using IFAT performed significantly better on the second test than those using Scantron and gave correct answers to more of the questions that they had initially responded to incorrectly on their first test in comparison to those students using the Scantron answer sheets. These results demonstrate that when students are actively engaged in the learning process and are given immediate feedback on their responses they learn from their mistakes and retain more information.

The studies described show how PI leads to increased conceptual understanding for students, how IFAT leads to greater retention, and explains why students find PI, CWDs, and clickers beneficial to their learning. These are not the only methods that lead to deeper understanding for students. Weiman & Perkins (2005) looked at the benefits of PI in combination with interactive computer simulations to help students become experts in physics. This study looked at data from introductory physics classes at the University of Colorado as well as using data from other sources. Previous studies (Hake, 1998) show that students perform better on the FCI post-test when they have been taught with PI over traditional teaching methods. Weiman and Perkins (2005) gave an example from their traditionally taught classrooms revealing that when students are asked a question directly following an explanation of a counter-intuitive concept, only 10% of the students gave the correct response. In addition to this they found, through a series of

interviews and surveys conducted with their students, that when students are taught in traditional classes they tend to learn how to solve physics problems by rote as opposed to using conceptual reasoning and they do not realize the links between physics and the real world. Students also experience cognitive overload in traditional classrooms because they are seeing too much information in a short period of time (Weiman and Perkins, 2005). This and other similar findings are what led the authors to explore alternate methods of teaching physics in order to increase retention and appreciation of the material being taught. The two approaches discussed by the authors were PI and using interactive computer simulations to teach physics. As shown by Crouch & Mazur (2001), Lazry et al. (2008), Hake (1998), and Nicol & Boyle (2003) when students were taught through PI they obtained greater conceptual understanding of the material because they were challenged to support their understanding or question their understanding in-class, instantly. It forced the student to think, and the student got immediate feedback. The moment of affirmation equaled the moment of learning for the student who understood “correctly”; it was the process of questioning their understanding that allowed the student who did not understand “correctly” to learn and undergo conceptual change. It was the active mental engagement that prompted this deep learning. An interesting result from Weiman & Perkins (2005) study was that the students at the University of Colorado developed a greater understanding of physics and an appreciation for the applicability of physics to real life phenomena through the use of interactive computer simulations over real life physical demonstrations. The explanation for this was that students have a tough time blocking out unnecessary distractions when they see real physical demonstrations. The computer simulations removed these distractions while still showing the applicability of the content.

Although the research supports the benefits of various active learning techniques such as PI, CWD and other interactive computer simulations, it is important to point out that PI benefits students to varying degrees depending on how it is implemented. Turpen & Finkelstein (2009) performed a study at the University of Colorado where they compared the PI teaching method employed by six different

introductory physics professors. The study consisted of in-class observations of the six professors as well as watching video recordings of their classes. The class sizes ranged from 130-240 students and the teachers had different levels of seniority and teaching experience.

In addition to being observed, the professors were asked to compare PI with traditional lecturing. They were asked about the importance of using clicker questions in the classroom, and about the ways they implemented PI. The authors developed a framework with 13 categories called dimensions of practice (DoP) that they used to determine to what extent each professor implements each of the PI dimensions in their teaching. The results of this study show that students who are taught with PI benefit to varying degrees from peer discussions and responding to clicker questions. These differences are due to the lack of consistency in the way the professors implement PI at the University of Colorado and therefore lead to some students benefitting more than others in their physics instruction.

The examples described so far have used clickers to implement active learning techniques in the physics, engineering, or biology classroom. In the absence of clickers, some teachers asked students to raise their hands for the correct response and some use flashcards. Lasry (2007) performed a study at John Abbott College with two first term CEGEP physics classes to see if one method, clickers or flashcards, led to a better understanding of physics for students. The classes were taught with identical content by the same teacher; the only difference was that one class used clickers and one used flashcards. Each class (approximately 40 students per class) was given the same FCI pre-test, FCI post-test, and final exam, and the results of all three tests were compared.

A two-tailed t-test was performed to check the significance of the results of this experiment. There was no significant difference in results for either class. Despite this, the author still recommended that teachers use clickers over flash cards for other reasons. First, if teachers use clickers in their classroom it gives them

incentive to use PI, which has been shown to increase students' conceptual physics understanding. Also, clickers have the benefit of being able to track student responses to questions. This can help teachers learn about students' misconceptions and inform future educational research. The final benefit highlighted by the author is that students can be re-arranged in the classroom and placed next to peers who have given a different answer to a question so as to increase peer discussion. This is possible because the clicker software registers and tracks each user.

The research described above directly or indirectly deals with student autonomy. "Autonomy represents an inner endorsement of one's actions—the sense that one's actions emanate from oneself and are one's own" (Deci & Ryan, 1987 quoted in Reeve & Jang, 2006, p. 209). When students are taught using PI, class-wide discussions, and interactive computer simulations, they become more autonomous because they are immersed in a student-centred learning environment where peer-interaction and debates are encouraged over students passively writing notes. When students are given the opportunity to challenge each others' views and have their own ideas challenged, they are able to teach and learn from their peers, thus feeling more involved in the learning process, developing an understanding about the material that they have thought through and developed for themselves. Research has shown that when students are encouraged to be autonomous they will be more engaged, volitional, and interested in the content (Reeve et al., 2004; Ryan and Powelson, 1991). It has also been found that students with teachers who support autonomy are more intrinsically motivated, have greater conceptual understanding (Grolnick & Ryan, 1987; Ryan & Grolnick, 1986), and higher academic performance (Black and Deci, 2000; Boggiano, Flink, Shields, Seelbach, & Barrett, 1993).

Black and Deci (2000) performed a study where they created a student-centred learning environment for college organic chemistry students that encouraged active engagement with the topics being covered in class. This was put into place with workshops led by advanced students (workshop instructors) and focused on

getting students to take part in group problem-solving and other participatory group activities that encouraged peer interaction and peer support. Each group included an instructor, an advanced student who was trained to encourage active engagement with the material being covered, and six to eight students. The groups met two hours per week throughout the semester. The students in the group filled out a questionnaire twice during the semester (once near the beginning and once near the end) about how much autonomy support they had from their instructors. The results of the questionnaires showed that students who felt that their instructors gave high autonomy support felt more competent in their abilities in organic chemistry, they had a greater sense of interest in the course, and they received higher grades on their exams than students who reported having instructors who did not support student autonomy. These results demonstrated the importance of students' perceptions of teacher support, students develop a greater appreciation and perform better in courses when they feel supported by their teachers' pedagogical approaches. When a teacher uses PI, there is an active partnership which develops between the teacher and the student. This partnership provides a sense of support while allowing the student to remain autonomous in their learning.

Minimizing pressure and control in the classroom has been shown to enhance student autonomy (Niemic and Ryan, 2009). When external motivators such as grades are removed from the picture, students become more relaxed since they are no longer worried about being penalized with a bad grade. This enables them to become more involved in the learning process, which in turn leads to a greater understanding of the course material. Benware and Deci (1984) showed that when college science students learned material with the intention of teaching it to their peers (similar techniques to those used in PI and CWDs), they were more motivated and showed better conceptual understanding of the material than students who learned the material solely to respond to test questions.

This literature review has shown how PI over traditional lecturing leads to greater conceptual understanding and improved performance on tests for college and



university students (Crouch & Mazur, 2001; Hake, 1998; Lazry et al. 2008; Mayor et al., 2009; Nicol & Boyle, 2003). It has also shown that students enjoy using clickers and feel that they enhance learning for a number of reasons (Barnett, 2006; Beatty, 2004; Martyn, 2007; Nicol & Boyle, 2003; Preszler et al., 2007). Two of these reasons are that students are actively engaged in the learning process and they find that receiving immediate feedback on their clicker responses helps them acquire a greater understanding of the course material. Dihoff et al. (2004) and Epstein et al. (2002) showed that when students are actively involved during learning and receive immediate feedback on assessments they do indeed develop a deeper understanding of course material. The studies described in this literature review deal, directly or indirectly, with student autonomy in the classroom. Black and Deci (2000) and Niemic and Ryan (2009) described the benefits for students in autonomous class settings. The following critical analysis will make use of these points to analyse what was observed in my own teaching practice when I altered my use of PI in the classroom, that is, when I went from asking students to raise their hands when responding to in-class multiple-choice questions to using clickers.

## **CHAPTER 3: RESEARCH QUESTION AND METHODOLOGY**

### **1 RESEARCH QUESTION**

This critical analysis seeks to explain what was observed when clickers were used to activate a PI approach as opposed to having students raise their hands. Informal teacher observations of how the students responded to questions in class and how they performed on tests suggested that the clicker class, when compared to the class that only raised their hand, had a deeper understanding of the concepts being learned. This analysis specifically asks:

Can the principles of constructivism explain why using clickers to respond to conceptual physics questions presented during a lecture, as opposed to only requesting a show of hands, results in increased learning?

### **2 METHODOLOGY**

There are three parts to the methodology for this critical analysis. First, the relationship between the pedagogical approach of PI and my conceptual framework, my literature review, and what I observed in my classes is examined. Second, a statistical analysis of the data that I collected in 2010, 2011 and 2012 which prompted my interest in comparing raised hands and clickers is presented, and third, the literature on PI and learning is used to explain what was observed.

The method I used to examine if clickers improved conceptual understanding and problem-solving skills was similar to that used by Crouch & Mazur (2001). In their study they gave students who were taught with PI in 1991 an identical final exam that had been given to students taught with traditional lecturing in 1985 and found that the overall average of the class taught with PI methods was significantly higher than classes taught using traditional methods. Another study that used a

similar method to this was one performed by Mayor et al. (2009). Their study compared midterm and final exam grades of three educational psychology college classes during different academic years (2005, 2006, and 2007) at the University of California, Santa Barbara. The three classes consisted of a group where the students used clickers in class (2006), one where the students answered multiple-choice questions during class without clickers (2007), and a control group that did not answer any multiple-choice questions during class (2005). The results were that the clicker group had a significantly higher average grade than the two other groups.

The method I used to get student feedback about using clickers was similar to the methods used by Barnett (2006), Martyn (2007), Nicol & Boyle (2003) and Preszler et al. (2007). Each of these studies asked students for their perceptions about using clickers during class. Martyn (2007) and Nicol & Boyle (2003) asked students to respond to a survey about the benefits of clickers in comparison to class discussions. The students in both studies preferred using clickers to class discussions. Barnett (2006) and Preszler et al.'s (2007) studies asked students in university science courses (biology and physics) about their perceptions of using clickers during class. The feedback was extremely positive from the students in both studies.

This study uses data collected in the Fall of 2010, the Fall of 2011, the Winter of 2011 and the Fall of 2012. Students in the Fall 2012 Physics NYA – Mechanics class, who used clickers to respond to conceptual questions during class lectures were given identical tests to students (in the Fall of 2010, the Fall of 2011 and the Winter of 2011) who responded to the same conceptual questions by raising their hands. The tests were taken from different terms (test 1 – fall 2010 term, test 2 – fall 2011 term, test 3 – winter 2011 term) but they all came from the same teacher and the classes were taught using identical content and teaching methods. The specific tests (fall 2010, fall 2011, and winter 2011) were chosen because they covered the appropriate content based on the scheduling of the term tests for the fall 2012 Mechanics class. The tests asked problem-solving based questions and

conceptual questions. The average test grades from the classes that used clickers (Physics NYA Fall 2012 class) were compared to the average test grades of the classes that answered the in-class multiple-choice questions by raising their hands (test 1 – fall 2010 class, test 2 – fall 2011 class, test 3 – winter 2011 class) to see if there was a significant difference between the performance of students using clickers versus the performance of students who responded to the teacher's question with a show of hands.

In addition to examining test grades, a questionnaire (using a five point Likert scale) was given to the students who used clickers to get feedback about the impact of PI on their learning (Appendices A and B). The questionnaire results will be used, along with results from Barnett (2006), Beatty (2004), Martyn (2007), Nicol & Boyle (2003) and Preszler et al. (2007), to support the benefits of using clickers over hand-raising in the classroom.

## 2.1 Participants/Sample

Subjects for this study were first year CEGEP students enrolled in Health Science, Pure and Applied Science, or the International Baccalaureate Science Programs. A convenience sample of classes taught by the same teacher was used for this research. Data was analysed from four classes of Physics NYA - Mechanics students (Fall 2012 – clicker class with 43 students, Fall 2010 – non-clicker class with 32 students, Fall 2011 – non-clicker class with 46 students, Winter 2011 – non-clicker class with 40 students). The questionnaires were given to the Fall 2012 Physics NYA – Mechanics class and the Fall 2012 Physics NYB – Electricity and Magnetism class (test scores for the NYB class were not analysed but the comments from the questionnaires were used to provide additional student feedback about using clickers) at the end of the semester.

## 2.2 Instrumentation

The instruments used for data collection were Physics NYA – Mechanics class tests (fall 2012, winter 2011, fall 2011, and fall 2010), Physics NYA – Mechanics (fall 2012), and Physics NYB – Electricity and Magnetism (fall 2012) responses to a questionnaire.

## 2.3 Research Design

Average test grades for classes taught without clickers (test 1 – fall 2010, test 2 – fall 2011, test 3 – winter 2011) were compared with the average test grades of a class taught with clickers (Fall 2012; tests 1-2-3). Tests given to the clicker classes were identical to tests given to students in the earlier semesters who were in classes that were taught by the same teacher with the same content (including all the same in-class conceptual multiple-choice questions) and teaching method but the students raised their hands in response to conceptual multiple-choice questions instead of responding to them using clickers. The students were given three tests over the course of the term and each test came from a different non-clicker class (different students taught in a different term). By doing this the average test grades used by the clicker class (fall 2012) were compared to average test grades from different non-clicker classes (test 1 – fall 2010, test 2 – fall 2011, test 3 – winter 2011).

A t-test comparing group means on incoming high school averages, average English 101 grades and Secondary V Physics grades was carried out to compare the overall academic background and achievement of the Fall 2012 cohort with the Fall 2010, Fall 2011, and Winter 2011 cohorts.

## CHAPTER 4: DATA ANALYSIS AND RESULTS

The data consists of (a) incoming high school averages, (b) average English 101 grades, (c) average Secondary V Physics grades, and (d) average grades on selected class tests in four different NYA Physics – Mechanics classes. Incoming high school averages and average English 101 grades were used to determine overall academic background and achievement. Background knowledge in physics was determined by analysing Secondary V Physics grades. A t-test for independent samples was the main method used for analysing the quantitative data. Note that the points with numbers next to them in Figures 1 – 4 are outliers and were not used in the statistical analysis.

In addition to average grades on selected class tests, results from a questionnaire were used to determine students' perceptions about using clickers instead of raising their hands to answer in-class multiple-choice questions.

### 1 GROUP COMPARISONS: ACADEMIC ACHIEVEMENT

The first question that was asked when carrying out this analysis was,

Is the Fall 2012 cohort (clicker class) equivalent to the Fall 2010, Fall 2011, and Winter 2011 cohorts (non-clicker classes) in terms of overall academic achievement as measured with incoming high school averages and their average English 101 grades?

#### 1.1 High School Overall Average

Table 1 and Figure 1 display the incoming high school averages of all four groups. There was no significant difference between the non-clicker classes and the clicker class.

Table 1  
Average High School Grades

GROUP	Mean	N	Std. Deviation
F2010	83.38	32	3.490
W2011	80.90	40	5.261
F2011	83.93	46	4.245
<b>F2012</b>	<b>84.02</b>	<b>43</b>	<b>5.718</b>
Total	83.09	161	4.941

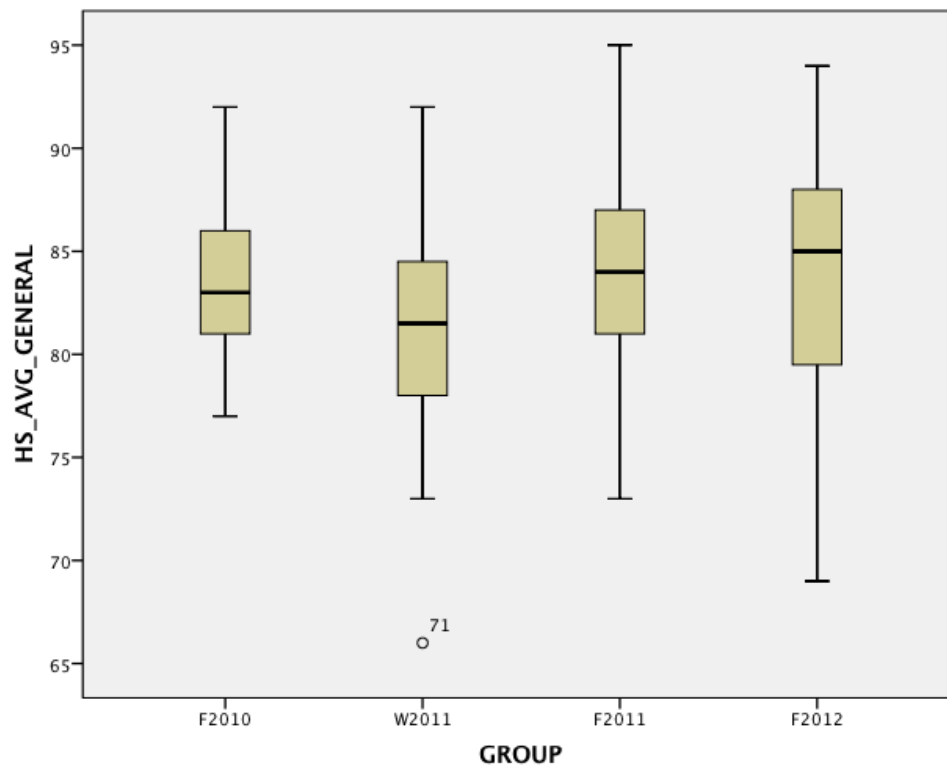


Figure 1 Average High School Grades

## 1.2 English 101 Grades

There was no significant difference in the English 101 averages among the four cohorts. This result and the non-significant comparison of incoming high school average grades demonstrate that the four cohorts came into CEGEP with equal academic ability. The average English 101 grades are summarized in Table 2 and Figure 2.

Table 2  
Average English 101 Grades

GROUP	Mean	N	Std. Deviation
F2010	78.81	32	9.836
W2011	77.85	40	7.658
F2011	80.98	46	6.888
F2012	81.19	42	11.793
Total	79.82	160	9.198



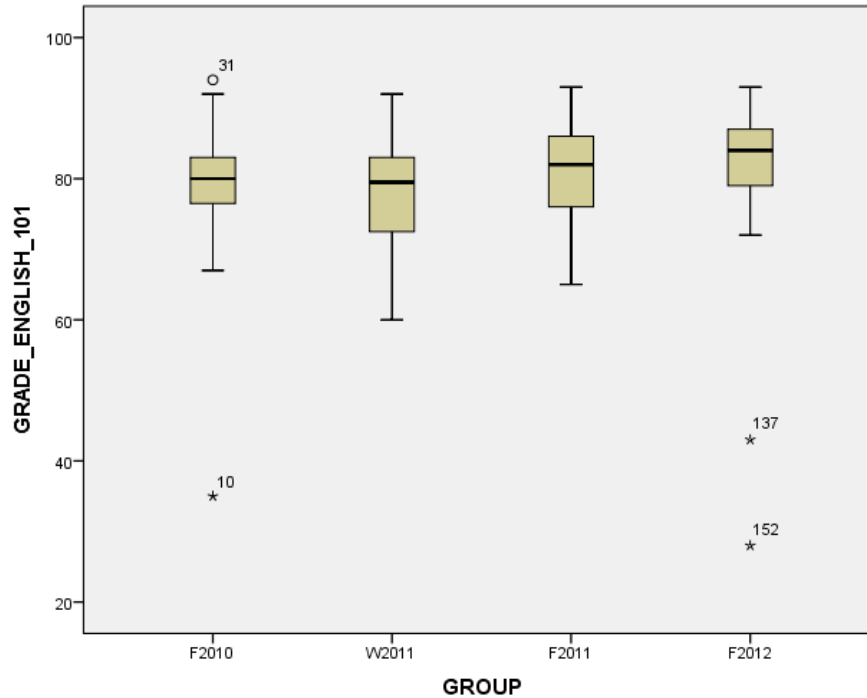


Figure 2 Average English 101 Grades

## 2 GROUP COMPARISONS: BACKGROUND KNOWLEDGE IN PHYSICS

The second question that was asked when carrying out this analysis was,

Is the Fall 2012 cohort (clicker class) equal to the Fall 2010, Fall 2011, and Winter 2011 cohorts (non-clicker classes) in terms of disciplinary background knowledge as measured with average Secondary V Physics grades?

A significant difference between the groups was found when comparing the average Secondary V Physics grades. The average Secondary V Physics grade for the Fall 2012 cohort was significantly higher than each of the other groups (between 0.664 and 0.669). Table 3 and Figure 3 summarize these results. The smallest difference (3.3%) was with the Fall 2011 cohort.

Table 3  
Average Secondary V Physics Grades

GROUP	Mean	N	Std. Deviation	Sig
F2010	81.31	32	6.203	0.669
W2011	77.26	35	7.006	0.664
F2011	83.34	44	6.706	0.664
F2012	86.64	42	6.347	
Total	82.43	153	7.347	

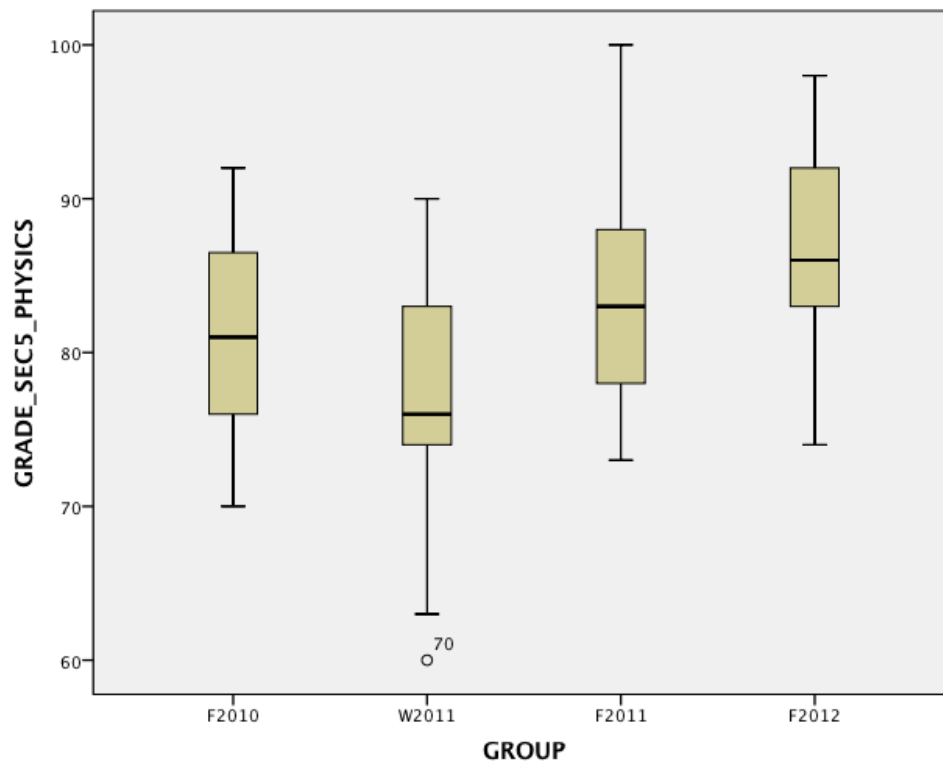


Figure 3 Average Secondary V Physics Grades

### 3 GROUP COMPARISONS: PHYSICS NYA TERM TEST RESULTS

The question asked when carrying out this analysis was,

Is there a statistical difference in the average grades received by students in NYA (Fall, 2012) (clicker) when compared with students from:

- a) NYA (Fall, 2010) on term test 1 (non-clicker)?
- b) NYA (Fall, 2011) on term test 2 (non-clicker)?
- c) NYA (Winter, 2011) on term test 3 (non-clicker)?

The average grade on term test 1 for the NYA Fall 2012 (clicker class) cohort was 78.54% and the average grade on term test 1 for the NYA Fall 2010 non-clicker class) cohort was 74.59%. As can be seen by these results (Table 4) the students who used clickers as opposed to a show of hands had a higher average test score by 3.95%. When looking at term test 2 the average grade was 81.88% for the NYA Fall 2012 (clicker class) cohort and was 72.16% for the NYA Fall 2011 non-clicker class) cohort. These results indicate (Table 4 and Figure 4) that students who used clickers as opposed to a show of hands had a higher average test score by 9.72%. The average grade on term test 3 for the NYA Fall 2012 (clicker class) cohort was 70.87% and the average grade on term test 3 for the NYA Winter 2011 non-clicker class) cohort was 64.15%. As can be seen by these results (Table 4) the students who used clickers over a show of hands had a higher average test score by 6.72%.

Table 4  
Average CEGEP Physics Tests 1, 2, and 3 Grades

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
Test 1	F2012	43	78.5407	18.93637	2.88777
	F2010	32	74.5859	18.11896	3.20301
Test 2	F2012	43	81.8837	15.68831	2.39244
	F2011	46	72.1576	16.10403	2.37441
Test 3	F2012	41	70.8659	18.43096	2.87843
	W2011	38	64.1513	20.78595	3.37193

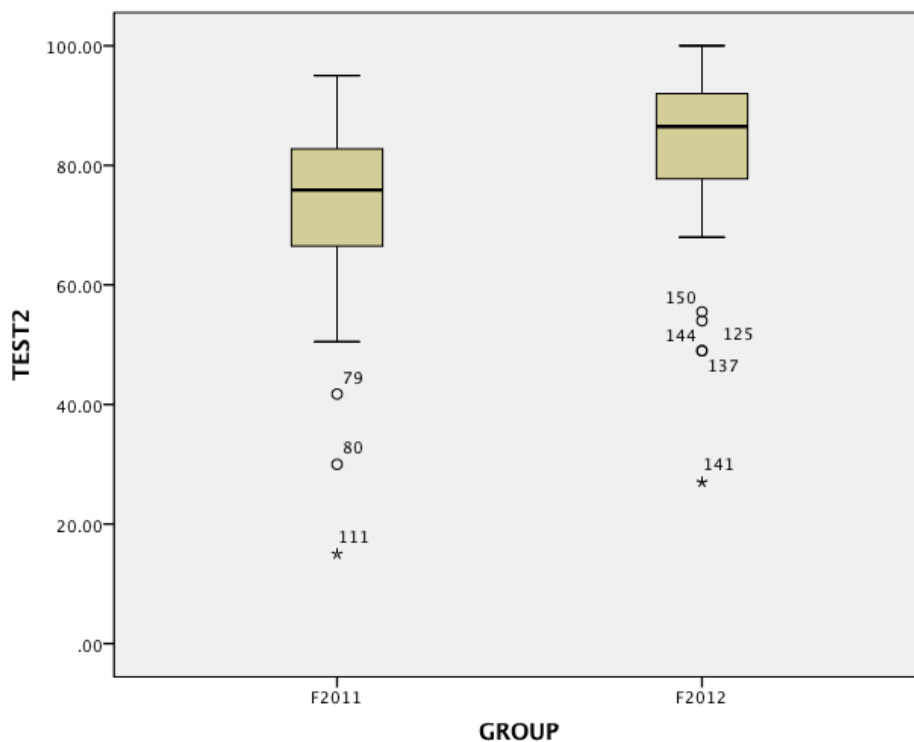


Figure 4 Average CEGEP Physics Test 2 Grades

The Fall 2012 NYA Physics – Mechanics cohort (clicker class) did perform better than the three non-clicker classes on all three term tests. Although the Fall 2012 cohort did have a significantly higher average in Secondary V Physics, which could indicate a stronger background knowledge when compared with the non-

clicker cohorts, their overall academic ability as measured by incoming high school averages and average English 101 grades were only marginally higher and these differences were deemed insignificant. It seemed that the use of clickers gave them an advantage. The results that provide the most support for this conclusion was the comparison between the Fall 2012 (clickers) class with the Fall 2011 (non-clickers) class on term test 2. These two groups were the most similar in terms of incoming academic achievement (0.09% difference in average high school grades and 0.21% difference in English 101 averages) and background physics knowledge (3.3% difference in average secondary V grades) but had the largest difference between their NYA average test grades (9.72%). The fact that the groups that were most similar at the beginning of their CEGEP term yet had the largest difference on their CEGEP physics test results indicates that clickers enabled the Fall 2012 cohort to deepen their understanding of physics as displayed by their test 2 results. The following section gives additional support for the use of clickers over hand-raising in the CEGEP physics classroom.

### 3 STUDENTS' RESPONSES TO USING CLICKERS

#### 3.1 NYA Physics – Mechanics Fall 2012

A questionnaire (Appendix A) was given to the Fall 2012 NYA Physics – Mechanics class to determine if they felt that using clickers affected their understanding of physics concepts. The students' responses to the Likert scale questions are displayed in Figures 5 – 10.

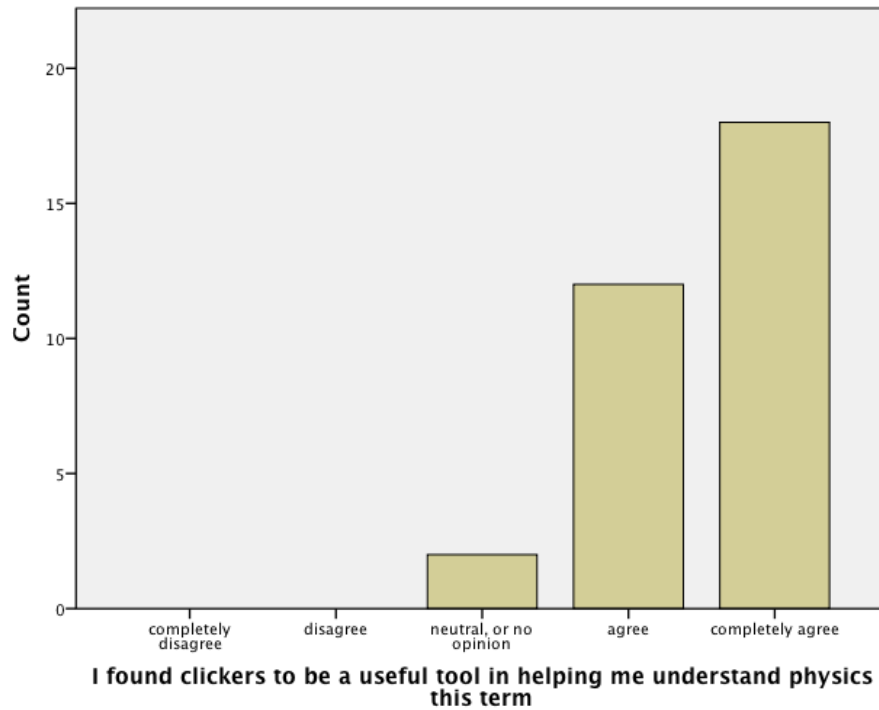


Figure 5 NYA (Fall 2012) students responses to question 1

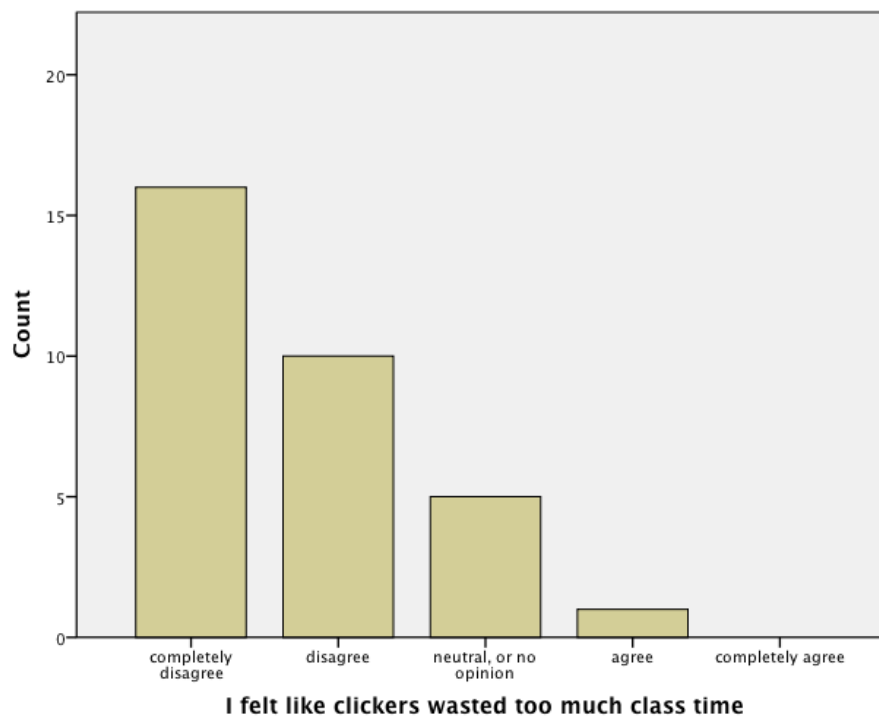


Figure 6 NYA (Fall 2012) students responses to question 2

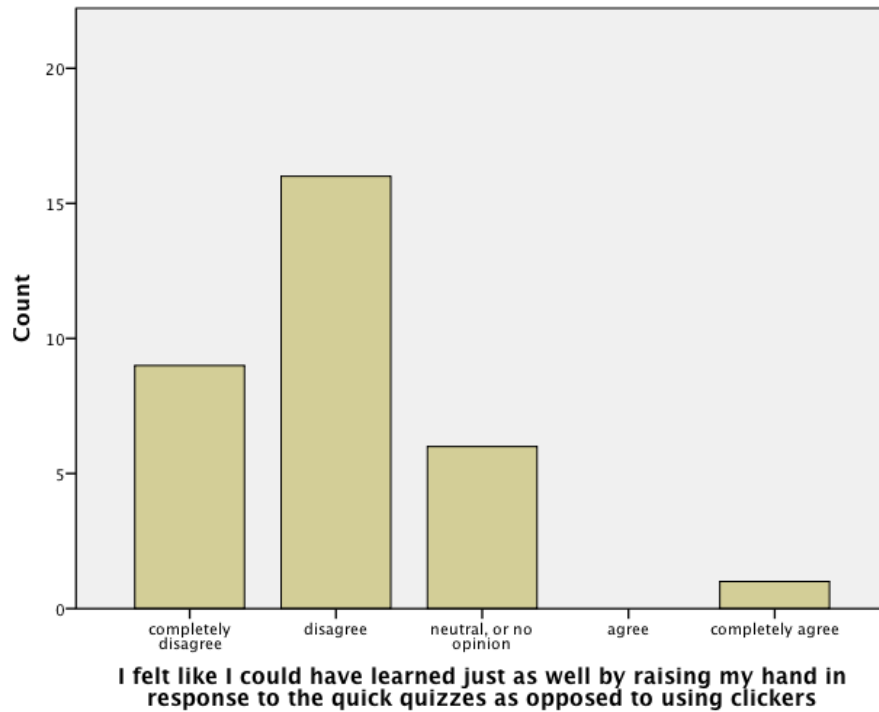


Figure 7 NYA (Fall 2012) students responses to question 3

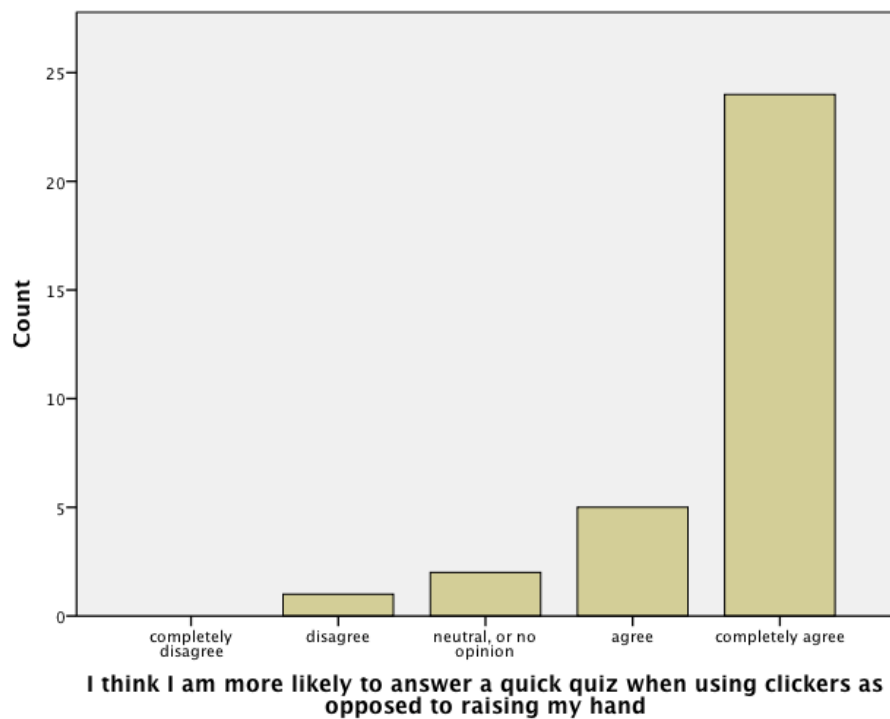


Figure 8 NYA (Fall 2012) students responses to question 4

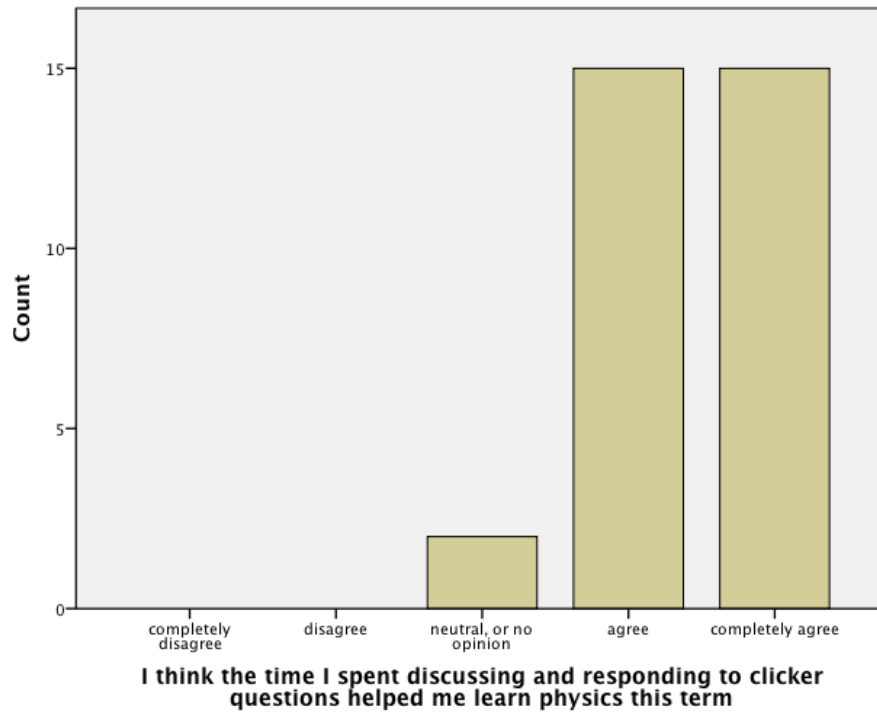


Figure 9 NYA (Fall 2012) students responses to question 5

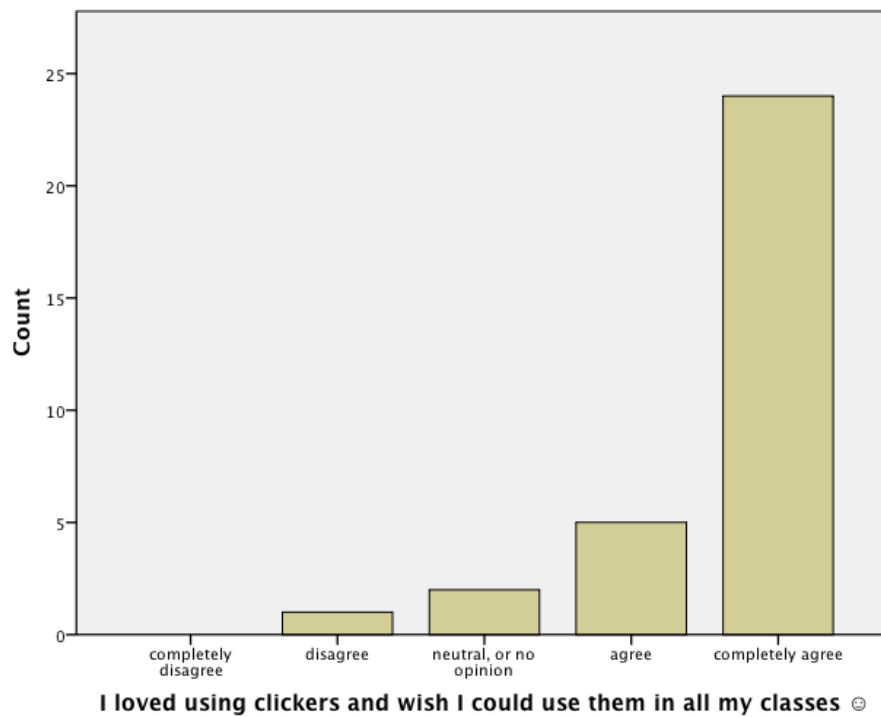


Figure 10 NYA (Fall 2012) students responses to question 6



All of the students' additional comments are reported below (many students did not write additional comments). Their comments have been coded into four themes: risk-free learning environment, interaction and motivation, conceptual change, and general satisfaction with using clickers.

#### Risk-Free Learning Environment

"I liked the fact that it is anonymous, so you can choose the answer that you think is right and make mistakes without feeling that others will think it is a stupid answer."

"Clickers allow shy people who are uncomfortable in answering questions participate in class."

"Nobody can see your choice, good thing."

#### Interaction and Motivation

"They were fun and allowed for time to interact with classmates that allowed for clarification from others. It gave a different point of view and overall the clickers were helpful for comprehension."

"Re-votes really helped because I got to discuss more and change my opinion."

"The questions were great to create discussion between students."

#### Conceptual Change

"The clickers were very good when the question seemed easy and you then realize it's not good. Continue not helping before asking the clicker questions as it makes us think more."

"Clicker questions were extremely helpful to understanding concepts that were difficult to grasp. These questions also enabled us to visualize some of the concepts seen in class."

"Re-votes really helped because I got to discuss more and change my opinion."

### General satisfaction with using clickers

“Clickers are a fun and exciting way to learn.”

“Excellent method to use in class. I’m very happy using clickers.”

“Suggest that other teachers use it!”

“Clickers are really useful tools. You should continue to use them. It is a great idea!”

“We all love clickers :D”

“I love clickers.”

“Respect clickers.”

“Clickers 4 life.”

The results of the Likert Scale and these comments indicate that the Fall 2012 NYA Physics – Mechanics class enjoyed using clickers and felt that using them positively affected their learning. No negative comments were written. These students were taught using clickers as opposed to raising their hands to answer in-class multiple-choice questions so they could not comment on the difference between the two teaching methods. There is no anonymity with hand-raising, therefore the comments in the first category show that clickers help students become more involved than they would if they were asked to raise their hands. Peer interaction takes place in both teaching environments (clickers and non-clickers) but if more students are voting in the clicker class this leads to increased discussion amongst the students. The same argument can be made for enabling students to undergo conceptual change. The fourth category shows that students enjoy using clickers in class. It makes learning game-like and therefore, fun.

### 3.2 NYB Physics – Electricity and Magnetism Fall 2012

A questionnaire (Appendix B) similar to that given to the Fall 2012 NYA Physics – Mechanics class was given to the Fall 2012 NYB Physics – Electricity and Magnetism class which was taught by the same teacher using clickers. No comparisons were done with these students' test grades but the results from the questionnaire are reported here since many of these students had the same teacher for previous physics courses. By giving them this questionnaire they were able to give feedback about the difference between hand-raising over clickers. Their responses to the Likert scale questions are displayed in Figures 11 – 16.

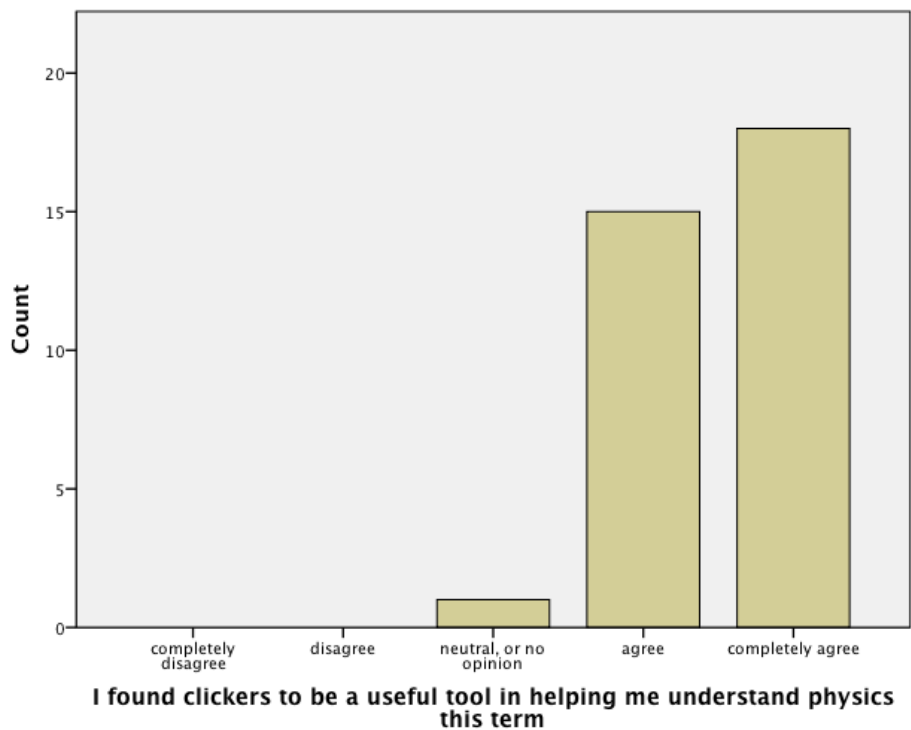


Figure 11 NYB (Fall 2012) students responses to question 1

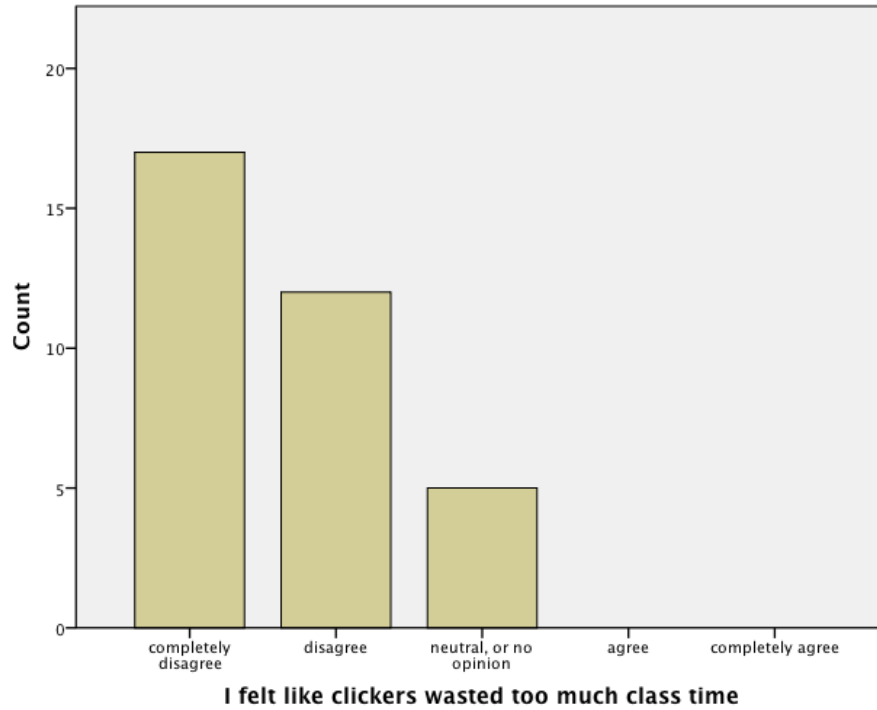


Figure 12 NYB (Fall 2012) students responses to question 2

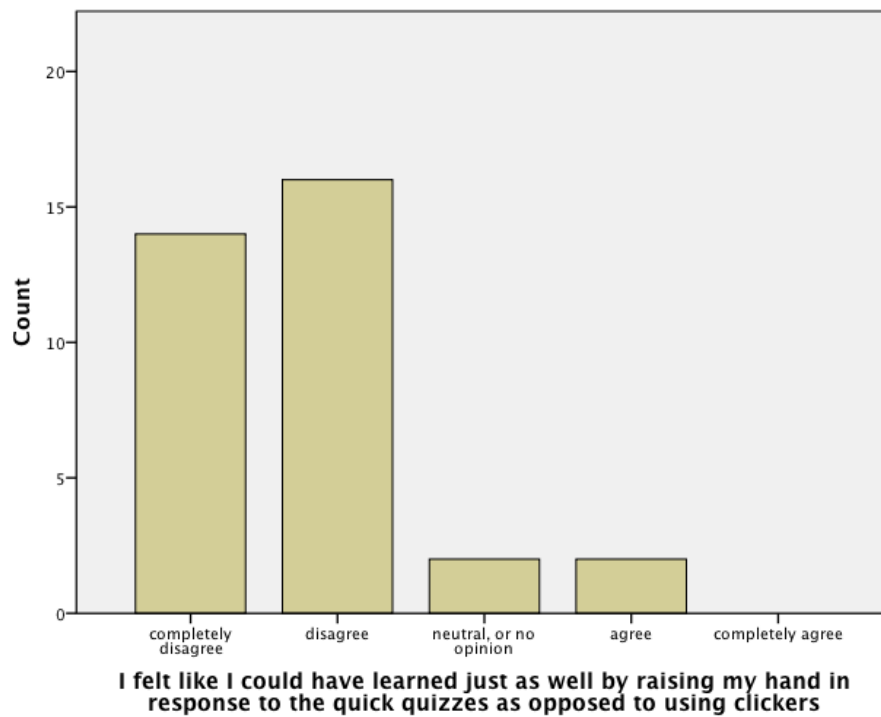


Figure 13 NYB (Fall 2012) students responses to question 3

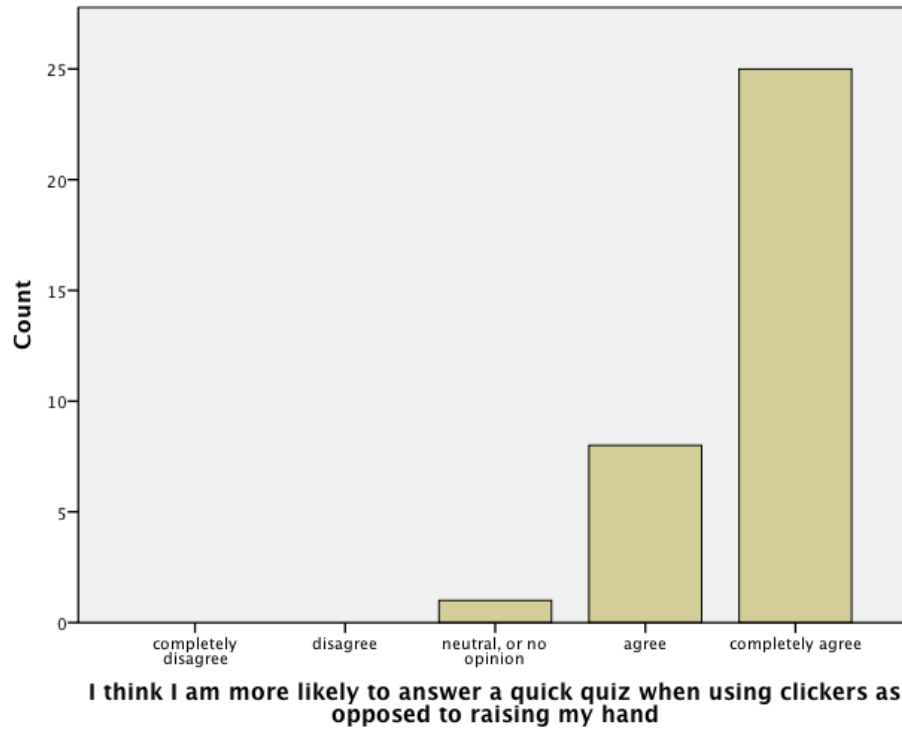


Figure 14 NYB (Fall 2012) students responses to question 4

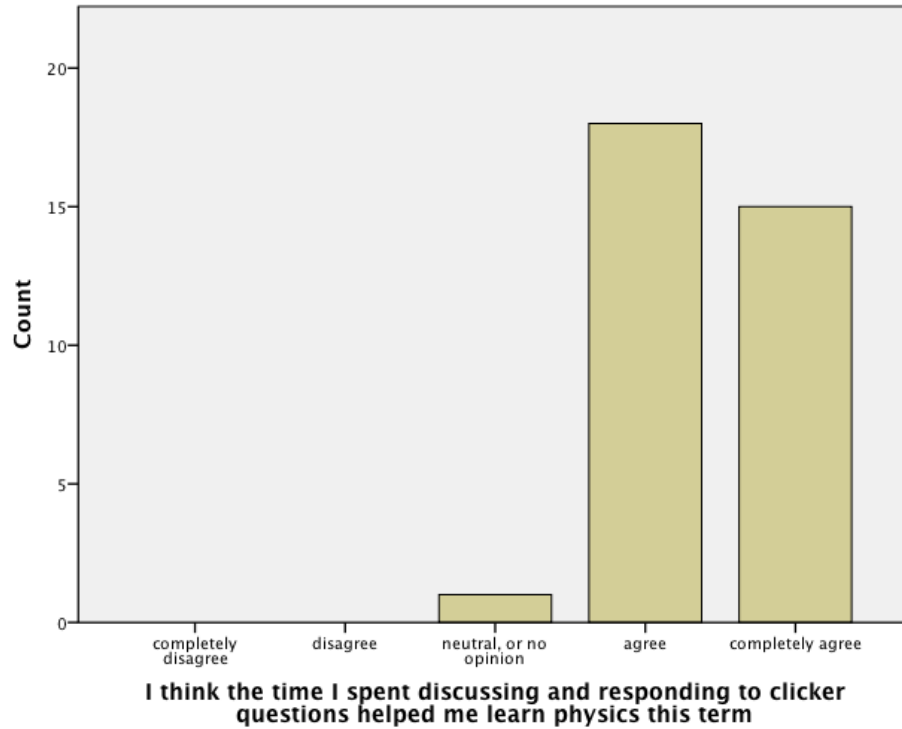


Figure 15 NYB (Fall 2012) students responses to question 5

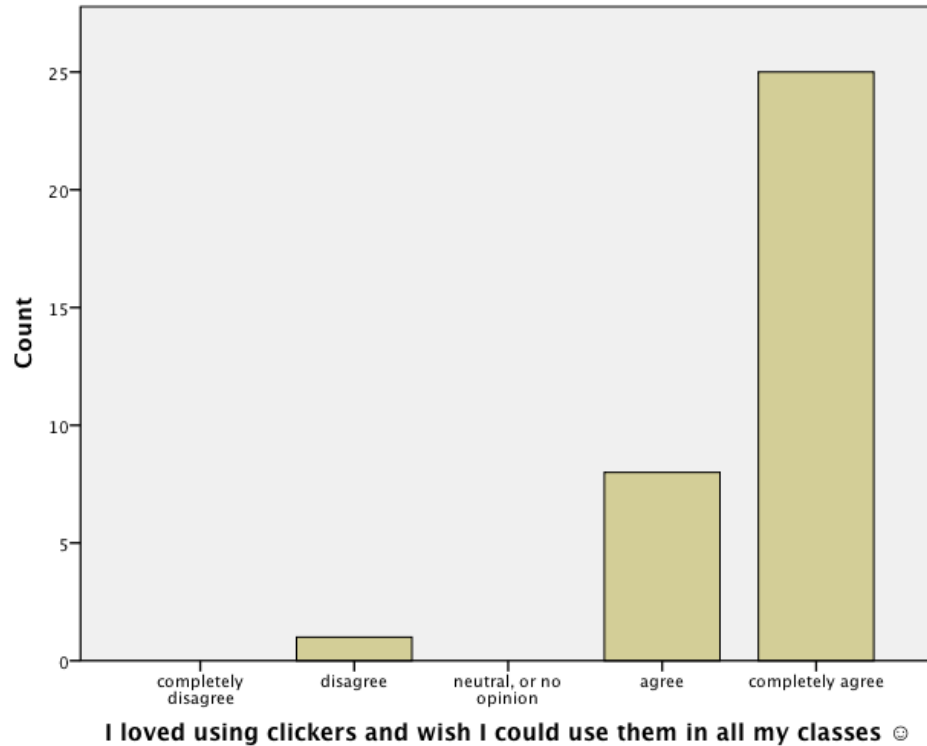


Figure 16 NYB (Fall 2012) students responses to question 6

The following question was asked to students in the Fall 2012 NYB Physics – Electricity and Magnetism clicker class who had had the same teacher in the Fall 2011 or Winter 2012 semester for a non-clicker (hand-raising) physics class,

Did you prefer using clickers over a show of hands when responding to quick quizzes? Why or why not?

Note that quick quizzes is the name given to the conceptual multiple-choice questions that are asked during class. All of the students' responses to this question (as well as their additional comments) are reported below. Their comments have been coded into three themes: risk-free learning environment, interaction and motivation, and conceptual change.

### Risk-Free Learning Environment

“It’s more fun this way, and I like how it’s anonymous.”

“Yes, because it is an anonymous vote, therefore I didn’t feel as “bad” when I got the wrong answer. I am more willing to answer the questions with the use of clickers.”

“I preferred clickers, people who are shy about answering questions incorrectly can do so in an anonymous way using clickers. Also more people answer when using clickers.”

“I preferred using clickers over a show of hands because we could really see the results. People were less shy and more inclined to use the clicker. Showing of hands gives people more opportunity not to respond.”

“Yes it is more interesting and you are not influenced by the rest of the class.”

“When raising hands, many people are not participating because they are too shy. With the clickers I think that you can really see if the class has a problem and solve it right away.”

“Very useful because answer is anonymous opposed to raising your hands which can create peer pressure and people will not want to answer their true answer.”

“Yes more fun and anonymous. Clickers are AWESOME!!!”

“Yes, less intimidating.”

“Yes I am more likely to read the question and I actually participate.”

“Yes I prefer quick quizzes with clickers since it’s anonymous.”

### Interaction and Motivation

“Yes, it made it more interactive. It also added suspense to see if you had answered the right answer, as you don’t see what everyone has voted right away.”

“I preferred using clickers when responding to quick quizzes because it made me more motivated to see if I got the right answer since we could see the distribution of answers from the class.”

Conceptual Change (These were written in additional comments and were not an answer to the above question.)

“They were fun. Learned from my mistakes when I didn’t get the right answer.”

“The clickers were a fun and amusing way to understand difficult concepts.”

These comments and the results of the six questions indicate that most students preferred using clickers. Based on their comments the biggest reason was the anonymity of clickers. There were no negative comments, implying that all of the students who responded to this survey enjoyed using clickers and felt that their learning was enhanced. This gives evidence that clickers are indeed superior to a show of hands.



## CHAPTER 5: DISCUSSION AND CONCLUSIONS

### 1 RELATIONSHIP BETWEEN CONCEPTUAL FRAMEWORK AND PI

Research has shown that peer instruction (PI) when contrasted with traditional lecturing leads to increased conceptual understanding and problem solving skills for physics students (Crouch & Mazur, 2001; Hake, 1998; Lazry et al. 2008; Nicol & Boyle, 2003). When students are forced to think about course material and are challenged to support or question their understanding of the concepts they are learning, they are more likely to develop deeper knowledge and experience conceptual change. This was observed in my own teaching practice when I began using PI (asking students conceptual multiple-choice questions during class time); my students became more interested in physics and displayed better conceptual understanding during class time as well as on their tests.

For the first few years of implementing PI, my students responded to these multiple-choice questions by a show of hands. When I replaced hand-raising with clickers I noticed a difference in my students' class involvement. I felt that this advantage for the clicker class over the non-clicker classes could not be explained by better background knowledge alone. This observation combined with a higher performance on class tests, provoked my in depth critical analysis of the literature. My question was, does using clickers as opposed to asking for a show of hands make PI more effective in terms of increasing student learning?

#### 1.1 Promoting Active Engagement

PI is a student-centred teaching technique based on constructivist principles. Constructivism posits that students make meaning for themselves by being actively involved in the learning process (Cobb & Yackel, 1996; Moshman, 1982; Shuell, 1986). Research suggests that when students actively engage with one another and

are given the opportunity to work things out together through logical arguments they retain more and develop a better understanding of the material being covered (Faust & Paulson, 1998; Springer et al., 1998). Constructivist settings encourage students to challenge others' ideas and to be open to having their own ideas challenged. These debates give students' the opportunity to combine new knowledge with existing knowledge as a way to create a more thorough and deeper understanding about the concepts being examined (Richardson, 2003). This is the main goal of PI. When students are immersed in a PI classroom environment they create new knowledge by discussing ideas they already have about the content, questioning those ideas and being introduced to new ideas through reasoning and debating with their peers. Even before students are given the chance to interact with their peers, they are encouraged to become actively engaged in order to better understand the course material. It has been shown that giving students some time to come up with their own responses to questions results in more students becoming actively involved during class, "the wait time gets all students thinking actively about the question rather than allowing them to rely passively on those students who are fastest out of the gate" (Faust & Paulson, 1998, p. 8). These students are actively engaged in the learning process and feel invested in the material being discussed since they have committed to an answer to the multiple-choice question. By committing to an answer, they are motivated to defend their choice before the revote and want the reinforcement that they are indeed correct (Beatty, 2004). If their choice is incorrect, they want to hear a good explanation defending and explaining the correct response. Students in a PI classroom are also more likely to pay attention during the period since they know that they will be asked multiple-choice questions about the concepts being covered (Mayor et al., 2009). The use of clickers in a PI classroom promotes an active, deep approach to learning because they encourage engagement and provide immediate feedback.

## 1.2 Promoting Conceptual Change

PI is an effective pedagogical approach for helping students undergo conceptual change. “Conceptual change is generally defined as learning that changes an existing conception (i.e., belief, idea, or way of thinking)” (Davis, 2001, p. 2). In order for conceptual change to occur, students must become aware of their misconceptions, discuss and evaluate them, experience conceptual conflict and then undergo conceptual restructuring (Davis, 2001). PI is designed to do exactly that. Students are asked a conceptual multiple-choice question and given time to think about it and come up with a response on their own. The discussion time and re-voting is where students have the chance to begin the process of conceptual change. After each student has submitted their initial response they are given the opportunity to defend it. “Dialogue can be effective because it ensures on the one hand that students understand the need to revise their beliefs deeply instead of engaging in local repairs (Chinn & Brewer, 1993), and on the other hand that they spend the considerable time and effort needed to engage in the conscious and deliberate belief revision required for conceptual change (Miyake, 1986)” (quoted in Vosniadou, 2007, p. 52). During the discussion time they may realize that another student’s response makes more sense than theirs (experience conceptual conflict). If this is the case, the student is now able to accept the correct response and undergo conceptual restructuring. This process of realization, acceptance and redefining one’s understanding about a given concept is extremely important for physics students as they often have misconceptions about many of the topics covered during their courses. If a student realizes that their initial response was incorrect, cognitive dissonance (stress arising from coming into contact with information that conflicts with one’s current belief) may occur (Festinger, 1962). In order to overcome cognitive dissonance (dissonance reduction), the student needs to restructure their understanding about the concept, thus making their new theory (the correct answer to the multiple-choice question) more appealing than the old theory (their initial incorrect response to the multiple-choice question). As the student is conflicted with the fact that their initial answer to the question was incorrect they must come up

with a clearer and more logical explanation for their new response. “The process of dissonance reduction should lead, after the decision, to an increase in the desirability of the chosen alternative and a decrease in the desirability of the rejected alternative” (Festinger, 1962, p. 95). As the student works this out on their own or with their peers they are actively involved in the learning process (ie. actively thinking about, re-examining and re-structuring their current thinking), thus developing a deeper understanding about the concept in question and undergoing conceptual change since they have thought about the topic in great detail and reasoned out exactly why it must be true. PI facilitates this intellectual process.

### 1.3 Fostering Deep Learning

PI seeks to create deep learners as opposed to surface learners since it forces students to think about the content right away and encourages them, on their own and through peer discussion, to think about the course material and make links between prior knowledge and experiences to the content being discussed. A deep autonomous learner is actively engaged with the subject and approaches learning in a different way than a surface learner. The result is that they develop a thorough understanding of the concepts. PI also makes use of Entwistle’s (2000) *student-focused learner oriented* conception of teaching where conceptual change is encouraged and students have the opportunity to acquire a more thorough understanding of the material being taught. Traditional lecturing, on the other hand, makes use of Entwistle’s (2000) *teacher-focused content oriented* conception of teaching and produces surface learners where students are encouraged to reproduce knowledge as opposed to questioning, discussing and thinking about the concepts being taught.

## 2 BENEFITS OF CLICKERS VERSUS HAND-RAISING WHEN IMPLEMENTING PI

Some teachers have argued that PI can be operationalized by simply asking students to raise their hand in response to a multiple-choice question (Lasry, 2007). My informal observations, the difference in grades between the F2011 vs. F2012 Physics NYA cohorts, and the student response to a survey on clicker use, strongly suggests that using clickers is preferable. The explanation for this can be found in the literature on learning and motivation.

### 2.1 Risk-Free Learning Environment

There are a many reasons that clickers are a better method for implementing PI over a show of hands. The first reason is that clickers, as opposed to a show of hands, create a risk-free learning environment where students can test their current thinking without revealing their identity or being worried that they will receive a bad grade. “The anonymity that an electronic system provides allows students to respond in a safe manner, which encourages them to take risks with their responses” (Martyn, 2007, p. 72). One of the disadvantages of hand-raising is that some students may be too shy or insecure to raise their hand (especially if no one else is putting their hand up). “Students in large classes are often hesitant or unwilling to speak up because of fear of public mistakes or embarrassment, fear of peer disapproval, pre-existing expectations of passive behavior in a lecture course—both on the part of lecturer and students” (Caldwell, 2007, p. 11). Another risk is that students may just wait to see what the majority votes and follow the pack – “the lack of privacy during voting [when students raise their hands] may prevent completely honest votes” (Caldwell, 2007, p. 12). Clickers eliminate these problems, as described by Barnett (2006, p. 477), “the proponents of these devices [clickers] claim that the privacy of student-device interaction takes away feelings of embarrassment felt by shy students when answering.” This was also found in my classroom, as mentioned in the data analysis and results chapter. The majority (11 out of 15) of the comments from my NYB students stated that they were more

comfortable using clickers over a show of hands because they were not worried about selecting the wrong answer. Students who are immersed in a risk-free environment, as in one where their identity will not be revealed and where they will not be graded on their performance, have shown to be more intrinsically motivated to learn and have been found to have greater conceptual understanding than students who have been given tests on the material learned (Benware and Deci, 1984). “Students’ autonomy can be supported by teachers’ minimizing the salience of evaluative pressure and any sense of coercion in the classroom, as well as by maximizing students’ perceptions of having a voice and choice in those academic activities in which they are engaged.” (Niemic and Ryan, 2009, p. 139) If external motivators such as test grades are removed, students feel more confident trying things out to see if they make sense and are more comfortable making mistakes since they know they will not be penalized with a bad grade. Students enjoy being able to debate and explain to other students why they chose a given answer and feel that they have played an active role in their own and their peer’s learning. This motivates them and encourages them to become and stay actively engaged during class.

## 2.2 Immediate Feedback

Another benefit of clickers over hand-raising is that they allow the teacher to receive instant accurate feedback about how well the students understand the concept. This in turn helps the teacher know how much more time should be used going over the given topic. “The instructor can adjust the lecture in mid-course, slowing down to spend more time on the concepts students find difficult or moving more quickly to applications of concepts of which students have a good understanding” (Faust & Paulson, 1998, p. 10). Caldwell (2007) and Majerich et al. (2011) also discuss the importance of formative assessments and how immediate feedback about these assessments enables the teacher to cater the lecture specifically towards the group of students being assessed. Similarly, Faust & Paulson (1998) describe how immediate feedback techniques, such as giving students quick tests during class (ie. asking multiple-choice questions), are useful in that they give

teachers formative assessments of students' comprehension on an ongoing basis throughout the lecture. This is an efficient way to find out instantly how well the class as a whole understands the concepts being covered during the lecture.

It has been shown (Price et al., 2011) that students are more likely to pay attention to, and make use of feedback if they receive it immediately. Clickers offer immediate feedback which give students the opportunity to recognize their mistakes and learn from them right away. Shute (2008) explains that students are more likely to take action based on feedback if it is obvious how they can apply the feedback right away and resubmit their work. When using clickers, students know immediately if their response is correct and are given the opportunity to submit a different response during the re-voting period. In Dihoff et al.'s (2004) and Epstein et al.'s (2002) studies they found that when students were able to continually answer multiple choice questions until they discovered the correct response their performance on tests improved. These studies demonstrate that when students are actively involved in the learning process, and receive instant informative feedback telling them if their responses to these multiple-choice questions are correct, they exhibit greater retention (improved test scores) over students who were less involved and receive no feedback when answering the same multiple-choice questions. In Barnett's (2006) study of introductory biology and physics students at the University of Western Ontario, the highest percentage of students (36.2%) claimed that receiving immediate feedback was the main advantage of using clickers. Barnett (2006) describes this benefit, "clicker technology supports behaviourism in that one of its major attractive qualities is the provision of swift feedback to students" (p. 477). Beatty (2004) also discusses how useful students find instant feedback. My students also describe this benefit (see data analysis and results chapter).

Barnett (2006), Caldwell (2007), and Nicol & Boyle (2003) discussed another benefit related to the immediate feedback feature of clickers; students like being able to see their results projected on a screen in class since it allows them to

see how well they understand the material in comparison to their peers. My students also mentioned the importance of this (see data analysis and results chapter).

### 2.3 More Time for Teaching

Using clickers over a show of hands saves class time. When asking students to raise their hands the teacher must gauge if the majority of students have been given enough time to formulate their answer. This could lead to a waste of class time if the teacher thinks the students need more time than they actually do or if the teacher is waiting, hoping to get more responses. Clickers eliminate this problem since the teacher can see the results as soon as the students press their button (Caldwell, 2007). My students commented about this advantage of using clickers (see data analysis and results chapter).

### 2.4 Interaction and Motivation

Clickers also give students an opportunity to discuss their responses with their peers and therefore be more involved during class than raising their hands would since the risk-free environment of clickers gets more students voting in the first place which means more students will defend their answer and challenge others' answers. Students enjoy being given the chance to interact with their peers during class as they often feel more comfortable debating with and learning from peers than they would with their teacher. "The strength of peer instruction is the interaction it fosters between students, who by virtue of their similar ages, language, and common experience, are often "better at clearing up each other's confusions and misconceptions" than their instructor" (Wood, 2004 quoted in Caldwell, 2007, p. 18). Barnett (2006), Beatty (2006), and Nicol & Boyle's (2003) studies found this to be the case. My students also cited this advantage (see data analysis and results chapter). Ryan and Powelson (1991) discuss the importance of students feeling supported, "in educational contexts and tasks where students experience support for their autonomy, and where they feel connected to and supported by significant



others, they are likely to be highly motivated” (p. 53). A PI classroom does exactly this. In this environment students are given time to interact with one another and come to their own conclusions about the material being discussed. It is through peer interaction that students become motivated and gain confidence in their ability to logically reason through a solution to the problem at hand. The biology students at the New Mexico State University in Preszler et al.’s (2007) article felt that clickers and peer discussion gave them a better understanding of their course material. My students also felt this way (see data analysis and results chapter). Peer discussions also enable students to understand the material better. Being actively involved in discussions leads to deeper conceptual understanding of the course material and promotes conceptual change because the student is engaged, works independently in concert with their peers to deepen their understanding (autonomy), and receives immediate feedback about whether their newfound understanding is correct.

## 2.5 Conclusion for the Benefits of Clickers Versus Hand-Raising when Implementing PI

The research explains why clickers were more effective than raising one’s hand. The anonymity of clickers gives students the confidence to select a response to the multiple-choice questions which leads to more students voting and becoming actively involved during class than if they were asked to raise their hands. This in turn leads to students being more likely to defend their response amongst their peers and to feel more motivated and engaged in the learning process. Since more students are voting, teachers are able to gauge how well the class as a whole understands the material and are able to adjust their lecture. By receiving immediate feedback and by giving students the opportunity to discuss their answers and re-vote, students increase their understanding, retain more information and perform better on tests. When students raise their hands they get an idea about their peers’ responses but fewer people are voting and some may be just going along with the majority. The results from clickers are clearly displayed on a screen in front of the class so everyone has more time to see how many people voted for each response than if students were raising their hands. Clickers also save class time since students submit

their responses right away as opposed to waiting for the teacher to ask them to raise their hands.

### 3 SUGGESTIONS FOR FUTURE STUDIES AND CONCLUSIONS

This critical analysis has explored how the pedagogical approach of PI uses constructivism to promote deep learning and conceptual change. It has also looked at the benefits of using clickers over a show of hands when implementing PI. In order to obtain more conclusive results from the data it would be beneficial to have a much larger sample, instead of looking at one NYA clicker class it would be useful to look at many clicker classes and compare them with non-clicker classes. When collecting this data the group characteristics (incoming average high school grades, average Secondary V Physics grades and average English 101 grades) between the clicker and non-clicker classes should be the same. This would make the results more accurate since it would help verify that the comparison groups are similar to begin with.

The study performed by Lasry (2007) also compared test grades between one clicker class and one class that used flash cards. This study found no significant difference between the test grades of the two groups. In order to find more conclusive evidence it would be useful for more clicker versus flash card comparative studies.

Mayor et al. (2009), on the other hand, did find a significant difference in midterm and final test grades when comparing a clicker class to a hand-raising class. They concluded that students who used clickers were more motivated to pay attention in class and more likely to develop the skills to determine how well they understood the class material thus leading to deeper knowledge.

Comparing test grades is not the only important factor in determining if clickers are more beneficial to student learning than hand-raising or other similar

techniques. Students' perceptions about their learning is also important. My NYB – Electricity and Magnetism students preferred using clickers to hand-raising due to the risk-free learning environment clickers created and felt that this increased their understanding and made class more enjoyable. Nicol and Boyle (2003) had similar findings, their students preferred clickers to class-wide discussions due to clickers being more anonymous than class-wide discussions. Based on the literature (Nicol and Boyle, 2003; Martyn, 2007; Barentt, 2006; Preszler et al., 2007) students find clickers enjoyable and extremely beneficial to their learning. Based on the data I collected from my clicker versus non-clicker classes in combination with all the supporting literature, it can be concluded that using clickers as opposed to asking students to raise their hands, results in increased learning.

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## **APPENDIX A - NYA PHYSICS QUESTIONNAIRE**

**NYA Physics Questionnaire Fall 2012**

For numbers **1 – 6** please read the statement and **circle** the number that corresponds to how much you agree or disagree with the statement using the scale given below.

1 = completely disagree

2 = disagree

3 = neutral, or no opinion

4 = agree

5 = completely agree

For question **7** please **write your response** in the space provided.

Please be honest in your responses, there are no right or wrong answers.

1) I found clickers to be a useful tool in helping me understand physics this term.

1                      2                      3                      4                      5

2) I felt like clickers wasted too much class time.

1                      2                      3                      4                      5

3) I felt like I could have learned just as well by raising my hand in response to the quick quizzes as opposed to using clickers.

1                      2                      3                      4                      5

4) I think I am more likely to answer a quick quiz when using clickers as opposed to raising my hand.

1                      2                      3                      4                      5

5) I think the time I spent discussing and responding to clicker questions helped me learn physics this term.

1                      2                      3                      4                      5

6) I loved using clickers and wish I could use them in all my classes 😊

1

2

3

4

5

7) Additional Comments?

Thank you for taking the time to fill out the questionnaire, it is greatly appreciated.

**APPENDIX B - NYB PHYSICS QUESTIONNAIRE**

## NYB Physics Questionnaire Fall 2012

For numbers **1 – 6** please read the statement and **circle** the number that corresponds to how much you agree or disagree with the statement using the scale given below.

1 = completely disagree

2 = disagree

3 = neutral, or no opinion

4 = agree

5 = completely agree

For question **7 - 9** please **write your response** in the space provided.

Please be honest in your responses, there are no right or wrong answers.

1) I found clickers to be a useful tool in helping me understand physics this term.

1                      2                      3                      4                      5

2) I felt like clickers wasted too much class time.

1                      2                      3                      4                      5

3) I felt like I could have learned just as well by raising my hand in response to the quick quizzes as opposed to using clickers.

1                      2                      3                      4                      5

4) I think I am more likely to answer a quick quiz when using clickers as opposed to raising my hand.

1                      2                      3                      4                      5

5) I think the time I spent discussing and responding to clicker questions helped me learn physics this term.

1                      2                      3                      4                      5

6) I loved using clickers and wish I could use them in all my classes 😊

1

2

3

4

5

7) Additional Comments?

If you have had Joanne Kettner as a physics teacher for a previous course please respond to questions 8 and 9.

8) Which previous physics course did you have Joanne Kettner as a teacher for?

9) Did you prefer using clickers over a show of hands when responding to quick quizzes? Why or why not?

Thank you for taking the time to fill out the questionnaire, it is greatly appreciated.