Peer Instruction (PI) is a student-centered educational method developed at Harvard by physicist Eric Mazur (Mazur, 1997). In PI, students use remote-control clickers that provide teachers with real time feedback for modeling the ongoing course. The method has been favorably received by the scientific community and implemented in various disciplines by a large number of US universities, given its common sense and documented effectiveness (Fagen, Crouch and Mazur, 2002; Crouch and Mazur, 2001; Mazur, 1997).

This article has four objectives. The first is to present the PI method to college teachers. The second is to assess whether or not PI is applicable to the CEGEP environment. Even though the method has been used effectively for over 15 years in US universities, this is the first study to document its effectiveness and applicability to a CEGEP in Quebec. The third objective is to determine whether PI is more effective than traditional CEGEP teaching. The last objective is to establish the contribution of clickers to learning.

WHAT IS PI?

SHORT HISTORY

In 1992, a team of physicists published a non-numerical diagnostic test of basic Newtonian physics concepts called Force Concept Inventory (I. A. Halloun, Hake, Mosca and Hestenes, 1995; Hestenes, Wells and Swackhammer, 1992). The authors of FCI designed the test to quantitatively measure the extent of preconceived ideas—often Aristotelian (DiSessa, 1982)—that students have of the world, in spite of previous training in physics. The FCI, a multiple-choice test, is unique in that it poses conceptual questions in simple terms and offers “distractors”, that is, other choices representing the erroneous concepts most frequently provided by students during interviews (I. Halloun and Estenes, 1985a, 1985b). To begin with, the test is easy. Students do not have to resort to memorized calculations or algorithms to answer the FCI questions. They are only required to pick the correct concept from among the “distractors”. By bringing these erroneous preconceptions to the forefront, the FCI makes it clear that students do in fact come to class not without knowledge but with many preconceptions.

Mazur decided to administer the FCI to his students at the end of the session. He minimized its importance for fear the students would mock such a rudimentary test. Quite to the contrary, the test left the students rather perplexed as expressed by the following question asked by one student: “Professor Mazur, how should I answer these questions? According to your teaching or based on my own understanding of these things?” (Mazur, 1997)

To Mazur’s great surprise, not only had students failed to understand several fundamental concepts after one or two years of high school training in physics (which, after all, enables them to enrol in Harvard), but a large number of preconceptions remained even after a session of his own teaching! Some students with the best grades had not grasped several basic concepts (Mazur, 1997). Coincidentally, this proved to be one of the most revealing conclusions of FCI data analysis. In fact, a meta-analysis of over 6,500 participants (Hake, 1998) shows that one traditional didactic session only marginally modifies students’ conceptual understanding.

DESCRIPTION OF THE METHOD

Mazur developed PI as an explicit response to his students’ preconceptions. This required some modifications to his traditional teaching method. In PI, the teacher makes a brief presentation to the students (7-10 minutes, within the average adult attention span). The content of the presentation is similar to the traditional curriculum except that basic concepts are emphasized to a greater
This study focuses on the following three research questions:

1. Is the Harvard PI method applicable to CEGEP?
   a. Is the method adapted to the institutional constraints?
   b. Can course structures be modified simply and in a feasible manner?
   c. How is PI received by administrators, fellow teachers and students?

2. Is the PI method more effective than the traditional didactic teaching methods used in CEGEP?
   a. Does PI increase conceptual learning?
   b. Does PI reduce traditional problem-solving abilities?

3. Is PI more effective with clickers than with flashcards?
   a. Does using clickers increase the conceptual change?
   b. Does using clickers impact students’ traditional problem-solving abilities in any way?

To answer a conceptual question, students simply press on the key that corresponds to the number of their answer and the data is instantly transmitted to the teacher’s computer. Using clickers also makes it possible for students to state their level of confidence (3 levels: High=H, Average=A, and Low=L) for each answer. In this way, the teacher can instantaneously determine the exact percentage of students with the correct answer as well as the distribution (in percentage) of each preconception. The ability to assess the extent of the group’s understanding in real time makes it possible for teachers to make a decision as to the progression of the course. If the concept under study is badly understood (<30% correct answers to the ConcepTest), the teacher will review the concept and explain it in greater detail before resubmitting the group to the ConcepTest. However, if the ratio of correct answers is very high (>80%), then the great majority of students have properly assimilated the concept. The teacher can then explain why the remaining choices are erroneous before moving on to the next concept. In most cases, the ratio of correct answers is neither very high nor very low. When there is a moderate range of correct answers (50%-80%), the teacher asks the students to try and convince each other of their choices. This leads to a 2-to-3-minute discussion between the students: Peer Instruction in action.

This discussion forces students to express their thoughts clearly, which leads them to a better representation of the concept. What’s more, a discussion among students sidesteps the element of authority that could intervene in a discussion with the teacher. Students are more likely to take the teacher’s explanation as “fact” without developing elaborately a form of reasoning as they would if they were discussing among peers. In addition to producing a more balanced debate, students also argue from conceptual starting points often unfamiliar to expert teachers. Due to their situation, students are often better equipped than teachers to understand the erroneous concepts of their peers, and this often facilitates conceptual modifications. After the discussion, students are submitted to the same ConcepTest and asked to vote again. The teacher then reveals the correct answer and explains why the remaining preconceptions are false.

According to results obtained in US universities, following a discussion among peers, not only does the rate of correct answers increase significantly but there is also an increase in the level of confidence expressed by the students for the correct answer (Crouch and Mazur, 2001; Fagen et al., 2002; Mazur, 1997).
in the study was randomly assigned to one of the three following experimental groups (PI groups and control group):

- PI group with clickers (n=41)
- PI group with flashcards (n=42)
- Control group (n=44)

The PI groups were taught by the author. The control group teacher was selected among the physics teachers because he was the closest to the author in terms of age (+/-3 years), years of teaching experience (+/- one year) and sex (M).

Furthermore, this choice was also motivated by the fact that students often described these two teachers as having similar teaching styles.

To isolate the specific contribution of technology in PI, the “clicker” group was compared to the “flashcard” group. However, to compare the effectiveness of PI on a conceptual learning level, the two PI groups were merged and compared to the control group.

RESULTS

APPLYING PI IN CEGEP

Applying new and somewhat costly educational methods in public institutions often runs into difficulties. However, the John Abbott college administration was behind the project from the very start. From the head of the physics department to the academic dean and the director of the sciences program, each intervener showed a genuine interest in PI and was more than supportive in helping implement the method.

Since the first test in physics, more than half of full-time members in the physics department (8/14) are actually using one form or another of PI in their class (with or without clickers). Teachers in the other departments have also been introduced to the method via lectures given in the college and by word of mouth. One teacher in the chemistry department used clickers successfully in his introductory course and plans on repeating the experience. A nursing teacher is currently using the method in her courses. A number of other teachers have inquired about the material and could soon decide to use it in their classrooms. Based on the reception received at the different administration levels as well as from the teachers in various fields, we can truly say that PI was warmly received by our CEGEP community.

RECEPTION FROM STUDENTS

Students were very receptive to using clickers in class. Students in the flashcard section were also satisfied with using flashcards. However, this satisfaction quickly
vanished when these students found out that the other section was using clickers. In order to measure the evaluation of the PI method in both the clicker and flashcard sections, students were asked to rate their level of agreement (5=totally agree to 1=totally disagree) with each of the seven statements below.

1. PI helped me recognize what I misunderstood.
2. PI showed me that other students had similar preconceptions to mine.
3. I actively discuss problems with classmates.
4. Having to convince other students helps me understand the concepts.
5. The mini presentations help clarify my understanding of the concept.
6. I learn better with PI than with traditional courses.
7. If I had to choose between a PI course and a traditional course, I would choose PI.

The answers were then grouped into three categories: agree/totally agree; neutral; disagree/totally disagree. To determine if students agreed with the statement beyond the expected probability, (2/5 or 40%), we calculated a binomial probability (agree p=0.4; disagree q=0.6; n=30).

Results show that students in the sections using either flashcards or clickers responded positively to PI by recognizing its advantages as statistically significant (p<0.05) as an educational approach (Q1-Q5) and by preferring it to traditional teaching (Q6 and Q7). In addition, 61% of students in the section using flashcards who were using clickers for the first time agreed that they would have been more actively involved if they had been given access to clickers rather than flashcards.

Other unsolicited yet interesting student reactions were found in the form of small computer drawings produced with Microsoft Paint and used as desktop screensavers on the computers in the physics laboratory. The Figure 5 presents the images that were found on computer screens in the physics laboratory after being used by PI students. These images were not present before the students arrived in the lab.

MODIFYING THE COURSE STRUCTURE

Using PI with clickers in class requires only minimal changes. To administer the ConcepTests where students vote using a clicker, you can enter or import the multiple-choice questions in PowerPoint. A number of ConcepTests can be found on the Internet at Harvard’s Project Galileo website2 or through publishers who include “clicker questions” in their manuals. Today, there are sufficient resources available that make using ConcepTests quite feasible.

Another change linked to the clicker technology is the familiarization with clicker material and software. It is strongly recommended that all interested teachers set up the clickers and receivers and try them a few times before attempting to use them in class.

In response to the first research question on applying the method in CEGEP, the results indicate that PI is quite feasible at CEGEP level. The modifications required to course structures are minor and achievable and the approach has been well received by administrators, teachers and students.

This being said, an educational method may be well appreciated without necessarily being effective. The following section examines the effectiveness of PI in CEGEP.

\[
\begin{array}{cccc}
\text{PI} & \text{Control} \\
\text{Pre-test} & 42.6 & 46.0 & \text{t-test (2-tailed)} \\
\text{Post-test} & 68.6 & 63.3 & 0.427 & 0.283 & 0.008 \\
\end{array}
\]

Table 1: FCI results for the PI group and the control group

\[
\begin{array}{cccc}
\text{Exam avg} \\
\text{PI} & 68.0 \\
\text{Control} & 63.0 \\
\text{t-test (2-tailed)} \\
\end{array}
\]

Table 2: Final exam for the PI group and the control group

These results demonstrate that even if there was no significant difference between the groups before teaching (p=0.427), the PI group achieved significantly more conceptual gains as measured by the FCI (p=0.008). This result confirms that PI is more effective for conceptual learning rather than traditional learning and reproduces as such the previous results obtained by Mazur (1997) and Hake (1998) outside American universities.

TRADITIONAL PROBLEM SOLVING

Physics teachers are sometimes hesitant to use non-traditional approaches such as PI. One of the concerns put forth is that the time spent explaining simple concepts implicitly takes away time for learning problem solving; an aptitude that must be demonstrated in summative exams. The following table shows the average obtained per group for the final exam.

These results indicate that PI students obtain better exam results, although not significantly (p=21), than their peers in the control group. We can, at the very least, affirm that the PI conceptual approach does not harm students as regards problem resolution. This is very likely due to the positive contribution of conceptual knowledge to problem-solving ability.

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\begin{array}{cccc}
\text{PreFCI} & \text{PostFCI} & \text{g (nom. gain)} & \text{Exam} \\
\text{Clickers} & 11.9 & 19.9 & 69.8 \\
\text{Flashcards} & 13.6 & 21.3 & 71.6 \\
\text{t-test (2-tailed)} \\
\end{array}
\]

Table 3: Differences in problem resolution (exam) and conceptual learning (FCI) between groups

These results show that in terms of conceptual knowledge, the two groups show no difference at the beginning (p=0.209) or at the end of the course (0.351) and that neither group learns more conceptually than the other (p=0.745). In terms of problem solving, the average grade for the final exam also shows no difference (p=0.650) between both groups. It is therefore possible to conclude that using clickers neither adds nor takes anything away from learning, whether conceptually or as regards problem solving.
In terms of traditional problem solving, PI students who spend more time working on concepts obtained better results than the control group students.

**LACK OF ADDED EFFECTIVENESS WITH CLICKERS**

One of the interesting and unexpected conclusions of this study is that using clickers does not provide students with a learning advantage. Certain previous clicker users in university classes reported advantages such as increased attendance rates and reduced attrition rates (Lopez-Herrejon and Schulman, 2004; Owens and al., 2004). Nevertheless, there is no data in this study to support the claim that clickers increase conceptual learning. PI is an elaborate educational approach that clearly emphasizes basic concepts. It requires that students commit to a conception and provides a setting for discussion among peers making it possible to go beyond misconceptions. It is obvious that the technology is not the pedagogy. However, since clickers add nothing to learning, should they not be abandoned?

The answer is no. In fact, we should actively encourage using clickers. Although this conclusion seems to contradict the previous finding, there are three main reasons for encouraging the use of clickers.

First and foremost, even if there is no difference in the amount of learning, appreciable differences exist in terms of teaching. It goes without saying that the accurate and automatic compilation of the distribution of answers is much more practical than having to count flashcards over and over again.

Secondly, clickers are to some degree responsible for the attention given to the PI method. A large part of this attention is due specifically to the use of clickers (Burnstein and Lederman, 2001, 2003). Many teachers, including yours truly, adopted the method thanks to the appeal of using clickers in their classrooms. So, implementing PI with clickers forces teachers to reconsider their teaching method, concentrate on concepts and, consequently, fundamentally reshape their teaching. Given that many teachers would not have given proper attention to PI had it not been for the clickers, it is important to continue encouraging their use.

Last but not least, using clickers in a classroom enables teachers to archive the data obtained in their ConcepTest. Beyond data analyses that can be addressed in a research framework, the data can also be used in an educational context to sort out useful ConcepTests from those that do not work as well. ConcepTests with debatable usefulness can then be reformulated. Clickers could make it possible for a series of questions to evolve from one session to the next. Using flashcards does not allow the teacher to gather data about the ConcepTest itself. As a result, the same questions are recycled from one session to the next. In terms of learning, questions that have been modified as a result of data collected should reveal learning differences when compared to a fixed sequence of questions used with flashcards. Some instructors may be aware of PI methodology and willing to reshape their instruction to provide greater focus on basic concepts. Yet, the capital expense for the purchase of clickers and related hardware may not be available and passing the expense onto the students may not be possible or desirable. In this instance, PI should be implemented with flashcards as it is the PI pedagogy that is effective, not the method students use to report their answers.

**CONCLUSION**

A number of science teachers still teach today the way they were taught, that is, the way we were taught during the last century (Beichner and al., 1999). Thanks to its appeal, the PI method could bring about a change in the way in which teachers and students perceive teaching. Its methodology requires very little modification to traditional teaching; it implies that greater emphasis
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be placed on basic concepts. The method does not come into conflict with current institutional constraints since it is generally well received by administrators, fellow teachers and students.

Although PI was developed at Harvard, it seems like an educational method that is effective in CEGEP and would benefit from being widely used and encouraged. The method is simple enough to allow for a systemic change in a relatively short time. This study also showed that using clickers does not add anything significant to learning. In fact, even though using clickers offers the teacher many advantages, their use does not increase the effectiveness of the PI method. The conclusion is that pedagogy must be seen as being distinct from technology.

BIBLIOGRAPHY


