A modified peer instruction versus teacher’s instruction

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Peer Instruction (PI) was introduced by Mazur [1] to help students learn physics concepts during lectures. Besides physics [2,3], PI has also been adopted in other STEM fields [4]. In this approach (Figure 1(a)), students answer a related question individually after a concept has been presented. Before they revote on the same question individually, they are asked to convince others their answer is correct during peer discussion. The percentage of correct answer typically increased after peer discussion [2,3]. However, Smith et al. [5] highlighted that the improvement may be due to copying, not because students actually learned how to reason correctly. To exclude copying, Smith et al. [5] modified Mazur’s PI protocol by adding a second question Q2 after the students revote on the first question Q1 (Figure 1(b)). Q2 is ‘isomorphic’ to Q1, meaning that it requires the application of the same concept but the ‘cover story’ is different [4]. The answer to Q1 is not revealed until after the individual vote on Q2. Here, we simplify Smith et al.’s PI protocol by removing the revote on Q1 (Figure 1(c)). Moreover, our Q1 and Q2 are similar, i.e. the same but some information given is different. Our PI protocol is thus the same as Mazur’s, except the pre and post discussion questions are not exactly the same. We compare the effectiveness of PI, in our protocol, to teacher’s instruction (TI) for a pair of similar questions, involving Lenz’s law, using Hake’s normalized gain [6] and a statistical test.

![Diagram](https://via.placeholder.com/150)

**Figure 1.** Variations of the peer instruction (PI) protocol. (a) Mazur’s protocol, (b) Smith et al.’s protocol, and (c) Our protocol. The answer to Q1 is not revealed until after Q2 is answered in (b) and (c).

The study was conducted in our first-year Physics for Engineering course over two semesters. The pair of similar questions involving the application of Lenz’s law is as follows
The smaller circle in Figure 2 is the cross section of a solenoid. The cross section of the solenoid, and the conducting loop both lie on the page. The magnetic field outside the solenoid is zero. The magnetic field inside the solenoid is uniform, where the magnitude $B_{\text{sol}}$ is given by $\mu_0 n i$. The current $i$ in the solenoid is _______ and _______.

(a) The magnetic flux through the conducting loop is increasing or decreasing?
(b) The current induced in the conducting loop produces a magnetic field. The direction of this magnetic field in the area bounded by the conducting loop is into the page or out of the page?
(c) The induced current in the conducting loop is clockwise (cw) or counterclockwise (ccw)?

The information given for the current in the solenoid is one of four possibilities: cw and decreasing, cw and increasing, ccw and decreasing, or ccw and increasing. For Q1, the current information is not the same for all students (to compel students to learn through peer discussion). Similarly for Q2.

![Figure 2. Cross section of a solenoid, and a circular conducting loop outside the solenoid.](image)

Each question is answered correctly only if all three parts are answered correctly; in this case 1 mark is awarded, otherwise, no mark is given. Before students attempted Q1, they were told that the probability of guessing all three parts correctly is only 0.125. After answering Q1, they were told Q2 will be similar to Q1, and they were asked to learn how to arrive at the answers to Q1 during peer discussion (Semester A, 39 students) and teacher’s instruction (Semester B, 95 students). As an incentive to do so, Q2 (like Q1) carries a small credit. 5 minutes were allocated for answering each question. The duration for peer discussion was 10 minutes. For teacher’s instruction (between 5 to 10 minutes), the instructor explained how to answer each part of Q1 generally as follows

(a) How to calculate the magnetic flux through a loop in a uniform field. The flux is $B_{\text{sol}} A_{\text{sol}}$, which increases (decreases) if the current $i$ increases (decreases).
(b) Firstly, how to use the right-hand-rule to determine the direction of the solenoid field. Secondly, how to determine the direction of the induced field: if the magnetic flux increases (decreases), the induced field points in the opposite (same) direction to (as) the solenoid field.
(c) How to use the right-hand-rule to determine the direction of induced current.

These points were already covered in the lectures in both Semester A and B, which is why we administered the pair of questions during the tutorial (problem-solving) session after the lectures. Near the end of the tutorial, the students worked on one practice question involving Lenz’s law, which requires the derivation of the formula for the terminal velocity of a conducting bar sliding on a vertical conducting rail in a uniform horizontal magnetic field. The solution to this practice question was discussed by the tutor/instructor before the students attempted Q1.
The percentage of correct answer (PCA) for Q1 is 46% and 43% for PI and TI, respectively (Figure 3), which is in the lower end of the 35%-70% range proposed by Couch and Mazur [2] for the definition of a challenging but not too difficult question. The PCA for Q2 is 59% for both PI and TI, which is 13% and 16% higher than the PCA for Q1 for PI and TI, respectively. Hake’s normalized gain, which is a rough measure of the effectiveness of a method of instruction, is defined as [6]

\[
\frac{\langle \text{post score} \rangle - \langle \text{pre score} \rangle}{100\% - \langle \text{pre score} \rangle}
\]

where <> denotes class average, which in our case is the same as the PCA. The normalized gain (actual gain divided by maximum possible gain) is 0.24 and 0.28 for PI and TI, respectively. In other words, based on this measure, TI is marginally more effective than PI.

Furthermore, the PCA for Q1(a) (i.e. part (a) on magnetic flux) is high, 80% and 78% for PI and TI, respectively (Figure 3). Moreover, the PCA for Q2(a) is very high, 95% and 93% for PI and TI, respectively. This shows that the low percentage (59%) of correct answer for Q2 (all three parts) for both PI and TI is mainly due to the inability of a high percentage of students in answering parts (b) and (c) correctly, which require a true understanding of Lenz’s law and the right-hand rule that relates current and field directions.

![Figure 3](image.png)

**Figure 3.** The percentage of correct answer for Q1, Q2, Q1(a) and Q2(a). PI: peer instruction. TI: teacher instruction.

To assess whether there was a statistically significant difference between the Q1 (pre instruction) and Q2 (post instruction) marks, we used the paired samples Wilcoxon test [7] instead of the paired samples t-test since neither Q1 nor Q2 marks are normally distributed. The test shows that the median of the differences between the paired marks is statistically significantly different from zero (p value = 0.027) for TI, but not statistically significantly different from zero (p value = 0.306) for PI. In other words, TI elicited a statistically significant change in student’s paired marks (from Q1 to Q2), but PI did not.

Hake’s normalized gain and Wilcoxon’s test show that TI is more effective than PI, in our protocol, for a challenging pair of similar questions involving Lenz’s law. It would be interesting to replicate our pilot study to see if the same conclusion holds. Furthermore, our study could be extended to other pairs of similar questions. Pairs of isomorphic questions, and different difficulty levels could
also be investigated. One could also study whether adding TI after PI in our protocol is more effective than either PI or TI alone.

References

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