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Peer Instruction in computing: The value of instructor intervention

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A B S T R A C T

Research has demonstrated that Peer Instruction (PI) is an attractive pedagogical practice in computer science classes. PI has been shown to improve final exam performance over standard lecture, reduce failure rates, contribute to increased retention, and be widely valued by students. In addition, a recent study using isomorphic (same-concept) questions found that students are learning during peer discussion and not merely copying from neighbors. Though this prior work is useful for evaluating peer discussion, it does not capture learning that takes place after peer discussion when the instructor further expands on the concept through a whole-class discussion. In the present work, isomorphic questions were used to determine the value of a PI question from start to finish: solo vote, group discussion, group vote, and instructor-led classwide discussion. The analysis revealed that the value of the instructor-led classwide discussion was evident in increased student performance over peer-discussion alone (raw gains of 22% compared to 14%). Moreover, the instructor-led discussion was highly valuable for all groups of students (weak, average, and strong) and was of particular value for weak students. Importantly, the largest gains were associated with more challenging PI questions, further suggesting that instructor expertise was valuable when students struggled.

1. Introduction

Peer Instruction (PI) is a pedagogical technique developed in physics that has since been used with considerable success in computing. At the core of this pedagogy is the ConcepTest (Crouch, Watkins, Fagen, & Mazur, 2007): a multiple-choice question answered by students typically using clickers. Each ConcepTest sets off a well-defined pedagogical protocol: students first answer the question individually (solo vote), then discuss the same question for several minutes with their neighbors, and finally re-vote on the question in light of the group discussion (group vote). Following the group vote, the instructor facilitates a classwide discussion and explanation of the ConcepTest, and can adjust the remainder of the class to target student difficulties.

In physics, it has been repeatedly demonstrated that PI vastly improves student performance on post-course concept inventories (Crouch et al., 2007; Hake, 1998). In CS, there are few concept inventories, and those that exist have not been widely deployed and established (Tew, 2010). Therefore, CS education researchers have used other metrics to measure the effectiveness of PI. PI in computer science has been found to improve final exam performance (Simon, Parris, & Spacco, 2013), reduce failure rates (Porter, Lee, & Simon, 2013), and contribute to improved retention (Porter & Simon, 2013).

In addition to overall student outcomes, the value of PI in the classroom can be measured quantitatively by the shift in student correctness between the solo vote and the group vote (Porter, Garcia, Glick, Matusiewicz, & Taylor, 2013; Simon, Kohanfars, Lee, Tamayo, & Cutts, 2010; Zingaro, 2010). Such numeric gains from peer discussion suggest, but do not imply, conceptual gains. Is peer discussion helping students conceptually, or are students largely copying from neighbors? Recent work by Porter, Bailey-Lee, Simon, and Zingaro (2011) used isomorphic questions to verify that students are indeed learning from the peer discussion.

Since PI is squarely a student-focused pedagogy, it is unsurprising that the nascent PI-CS literature has focused on determining the value of the peer discussion portion of PI. However, measuring gains *solely* from peer discussion may underestimate the total learning conferred

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through a PI ConcepTest. Each PI cycle concludes with the instructor providing the correct answer and engaging in a classwide discussion meant to provide students with knowledge uniquely held by a subject matter expert: illuminating each response choice, discussing why the concept is important at large, and aiding students in integrating this concept with other concepts in their construction of increasingly expert-like maps of core disciplinary areas. This "instructor intervention" must be captured if we are to truly evaluate student learning from PI ConcepTests.

In this paper, we offer the first account in CS education of the additional benefits conferred through instructor intervention. We also offer the first account in the sciences of the effect of question difficulty on learning gains conferred through peer discussion or instructor intervention.

We conducted a controlled experiment on a large introductory computer science (CS1) class in order to compare peer discussion alone versus peer discussion combined with instructor intervention. We find statistically significant differences between these two modes, clearly demonstrating the importance of instructor intervention within the peer-based PI framework. In addition, we conduct analyses on student ability groups and find that instructor intervention is particularly useful for low-performing students.

The contributions of this paper include:

- A first CS study that measures both peer learning and instructor-led learning. We compare these results with a similar study in biology (Smith, Wood, Krauter, & Knight, 2011).
- Evidence that instructor-led discussion is valuable for weak, average, and strong students alike.
- Evaluation of question difficulty demonstrating that difficult questions are particularly valuable for student learning.

2. Background and related work

While our focus in this paper is the PI pedagogy, we note briefly that the CS research community is currently investigating many active and collaborative forms of teaching and learning. For example, the flipped classroom, pair programming, and lectures supported by visualizations (Kaminski, 2008; Lockwood & Esselstein, 2013; McDowell, Werner, Bullock, & Fernald, 2006) have all been advanced as alternatives or complements to traditional lecture-based teaching.

2.1. Peer Instruction

As described previously, each cycle of the in-class portion of "classic PI" involves students answering a question on their own (solo vote), discussing with their neighbors, and voting again (group vote); see panel A in Fig. 1. Following the group vote, the instructor leads a classwide discussion related to the core concept and its misconceptions. The instructor may lecture briefly, or ask students to explain why specific distractors were compelling ("Why did you choose A? What misunderstanding might have led you to choose B?").

Core to the implementation and evaluation of PI is the use of clickers: small devices, similar to television remote controls, that enable students to transmit responses to the instructor's base receiver (Blasco-Arcas, Buil, HernáNdez-Ortega, & Sese, 2013). Clickers provide students a low-risk, "fun" technology with which to commit to response choices and engage with the material (Knight & Wood, 2005; Simon et al., 2010). While others have argued that learning is equivalent whether clickers or flashcards are used (Lasry, 2008), clickers afford the

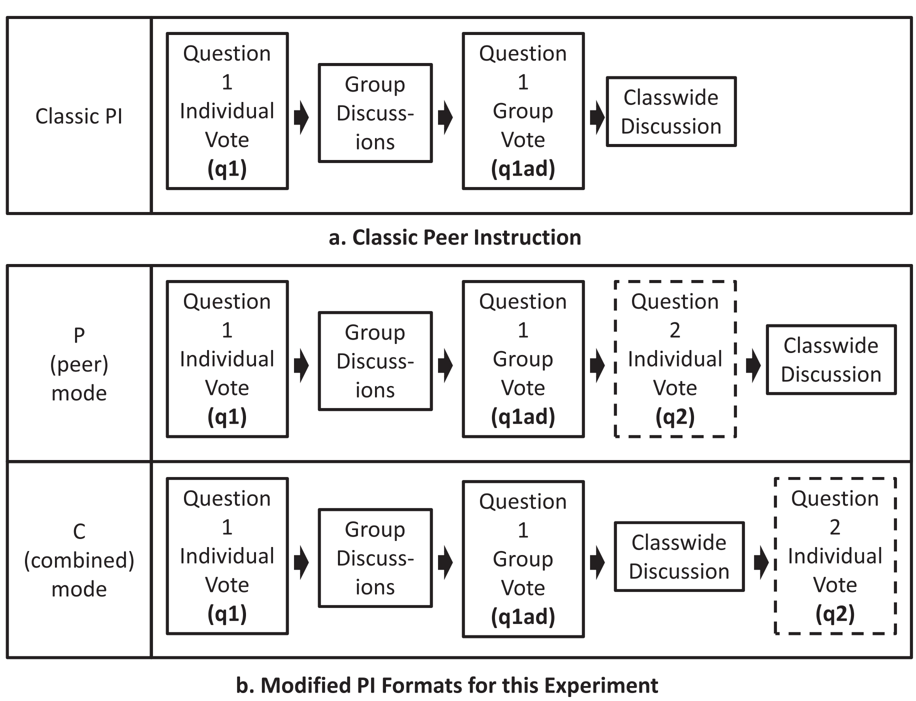

Fig. 1. The P (Peer) and C (Combined) administration modes used in the study.