Evaluating the Use of Peer Instruction in Civil Engineering Courses

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Introduction and Objectives

Interactive teaching strategies have demonstrated the ability to increase learning gains when compared to traditional lecture style approaches (Freeman et al. 2014). One such strategy, Peer Instruction (PI), aims to convert students from passive listeners to active and engaged learners. Peer Instruction has five basic iterative steps: (1) the instructor asks a conceptual question; (2) students think about the question; (3) students make an initial vote using a personal response system (PRS); (4) if a significant proportion of the class is confused, students engage in peer discussion moderated by the instructor; and (5) students vote individually again (Vickrey et al. 2015, Mazur et al. 1997). A flowchart for the PI process is shown in Figure 1.

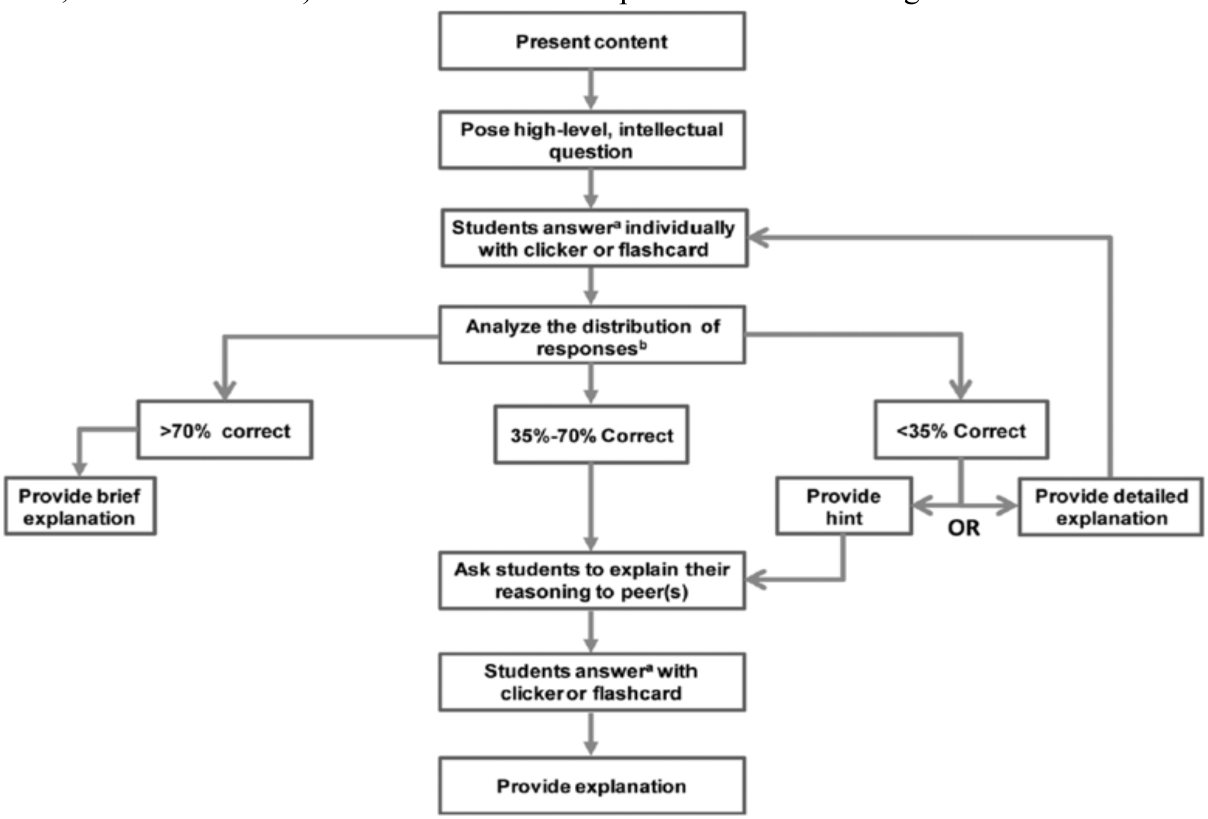

Figure 1. Peer instruction flow chart (courtesy of Vickrey et al. 2015)

PI has been evaluated for its efficacy as an instructional strategy in the natural sciences including chemistry, biology and physics (Crouch and Mazur 2001; Golde et al. 2006), but there are few studies evaluating the use of PI in engineering education. In this study, we are evaluating the use of PI in civil engineering courses taught at the University of Nebraska-Lincoln during the 2017-2018 academic year including a required introductory environmental engineering course (junior level, n=50,) an elective course in structural engineering (senior and graduate students, n=11) and an elective course in transportation engineering (senior and graduate students, n=15) taught via synchronous distance education. In each course, one-half of the course topics were covered using a PI approach. Assessment techniques in this study included a pre- and post-knowledge test to evaluate student learning; Classroom Observation Protocol for Undergraduate STEM (COPUS) analysis of classroom activities, and a student satisfaction survey administered at the end of the course. From these assessment techniques, we measured learning gains on topics presented using PI versus traditional lecture styles and student satisfaction with using PI in engineering classrooms. We hypothesize that the use of PI will increase the classroom time spent by both the instructor and students in active teaching and learning modes and will result in learning gains by students. Finally, we anticipate that the use of PI will increase student satisfaction with the course and that students will recommend the continued use of PI in civil engineering courses. To our knowledge, this study is one of the first to evaluate the efficacy of PI in civil engineering education.

Approach

The use of PI was evaluated in three courses taught during the 2017-2018 academic year: a required junior level introductory environmental engineering course and an elective cross-listed senior level and graduate course in structural engineering were both taught in the Fall 2017 semester. Evaluation of PI in an elective cross-listed senior level and graduate course in transportation engineering is on-going during the Spring 2018 semester. In this paper, preliminary results from the Fall 2017 semester will be presented.

In each course, the instructor developed PI questions to cover approximately one-half of the course topics and the other half of the course topics were covered without the use of PI. In both courses, the topics covered by PI were selected such that the PI and non-PI topics were alternated throughout the semester. A knowledge test was developed by the instructor for each course and was administered at the beginning and end of the course to evaluate learning gains. In the environmental engineering course, this was structured as 18 multiple-choice true false questions with three to four stems per question for a total of 61 responses. In the structural analysis course, this was structured as 20 multiple-choice questions. Example questions are shown in Figures 2 and 3.

1. Continuously mixed flow reactors:
   - A Represent a system where contents are instantaneously mixed T F
   - B In these reactors, the composition of the influent is equal to the composition within the tank T F
   - C Typically represent flow in pipes and rivers T F

Figure 2. Example question from pre- and post-knowledge test for environmental engineering course.

13) For a typical frame element solved using the matrix structural analysis approach, what assumptions are made? (select two responses)

(a) Deformations are small
(b) Flexural and axial stiffnesses are un-coupled
(c) Flexural and axial stiffnesses are coupled
(d) Frame element has no shear forces

Figure 3. Example question, number 13, from pre- and post-knowledge test for structural engineering course.

Classroom activities from topics covered with and without the use of PI were video recorded and evaluated using the Classroom Observation Protocol for Undergraduate STEM (COPUS) as described in Smith et al. (2013). In the Introduction to Environmental Engineering course, six class periods were recorded, three that included the use of PI and three that did not include PI. Similarly in the Advanced Structural Analysis course, 4 class periods were recorded, 2 that included the use of PI and 2 that did not include PI. At the end of the course, a student satisfaction survey was administered using an instrument adapted from Crossgrove and Curran (2008). All data collection activities were reviewed and approved by the University of Nebraska-Lincoln Institutional Review Board (IRB approval number 20170817452EX).

Results

The demographics for both the environmental engineering and structural engineering courses are reported in Table 1. 43/50 (86%) and 11/11 (100%) students completed the demographics survey in the environmental engineering and structural engineering courses, respectively.

Pre- and post-assessment data from PI and non-PI topics were used to calculate average normalized learning gains. In the environmental engineering course, the average normalized learning gain for PI topics was 0.48, and was 0.45 for non-PI topics. The results for this course were not statistically significant, with a p-value of 0.356 (one-tailed T-test) and an effect size of 0.078 (Cohen's *d*), placing it into the category of very small effects (Maher et al., 2013). In the structural engineering course, the average normalized learning gain for PI topics was 0.70, and was 0.25 for non-PI topics. The results for this course were statistically significant, with a p-value of <0.001 (one-tailed T-test) and an effect size of 1.22 (Cohen's *d*), placing it into the category of large effects.

In the environmental engineering course, 43/50 (86%) of students also completed the student satisfaction survey. 22/43 students (51%) reported having a previous course that used peer instruction, while 41/43 students (95%) reported participating in peer instruction activities in this course. In the structural engineering course, 6/11 (54%) of students reported participating in peer instruction activities in prior courses, while 11/11 (100%) reported participating in peer instruction in this course. Results from the student satisfaction surveys from both courses are shown in Figures 4 and 5. Analysis of COPUS data is on-going.

Table 1. Demographics for environmental engineering (ENVE) and structural engineering (STR) courses.

Gender	ENVE	STR
Male	77%	82%
Female	21%	18%
Did not respond	2%	0%

Education Level	ENVE	STR
Freshman	0%	0%
Sophomore	7%	0%
Junior	58%	0%
Senior	33%	55%
Graduate Student	2%	45%

Race/Ethnicity	ENVE	STR
American Indian/Alaska Native	0%	0%
Asian	2%	9%
Black or African American	0%	0%
White	86%	55%
Non-Resident Alien	2%	18%
Hispanic/Latino	0%	18%
Native HI/Pacific Islander	0%	0%
Two or more Races	2%	0%
Race/ethnicity unknown	2%	0%
Did not respond	5%	0%

Student Status	ENVE	STR
Full Time	93%	100%
Part Time	7%	0%

Marital Status	ENVE	STR
Single	79%	100%
Married	19%	0%
Divorced/Separated	2%	0%

Disability Status	ENVE	STR
Hearing Impairment	0%	9%
Visual Impairment	0%	0%
Mobility/Orthopedic Impairment	0%	0%
Other	2%	0%
None	93%	91%
Did not respond	5%	0%

First Generation College Student	ENVE	STR[1]
No	95%	82%
Yes	5%	9%

[1] There was one student who did not respond to this question.

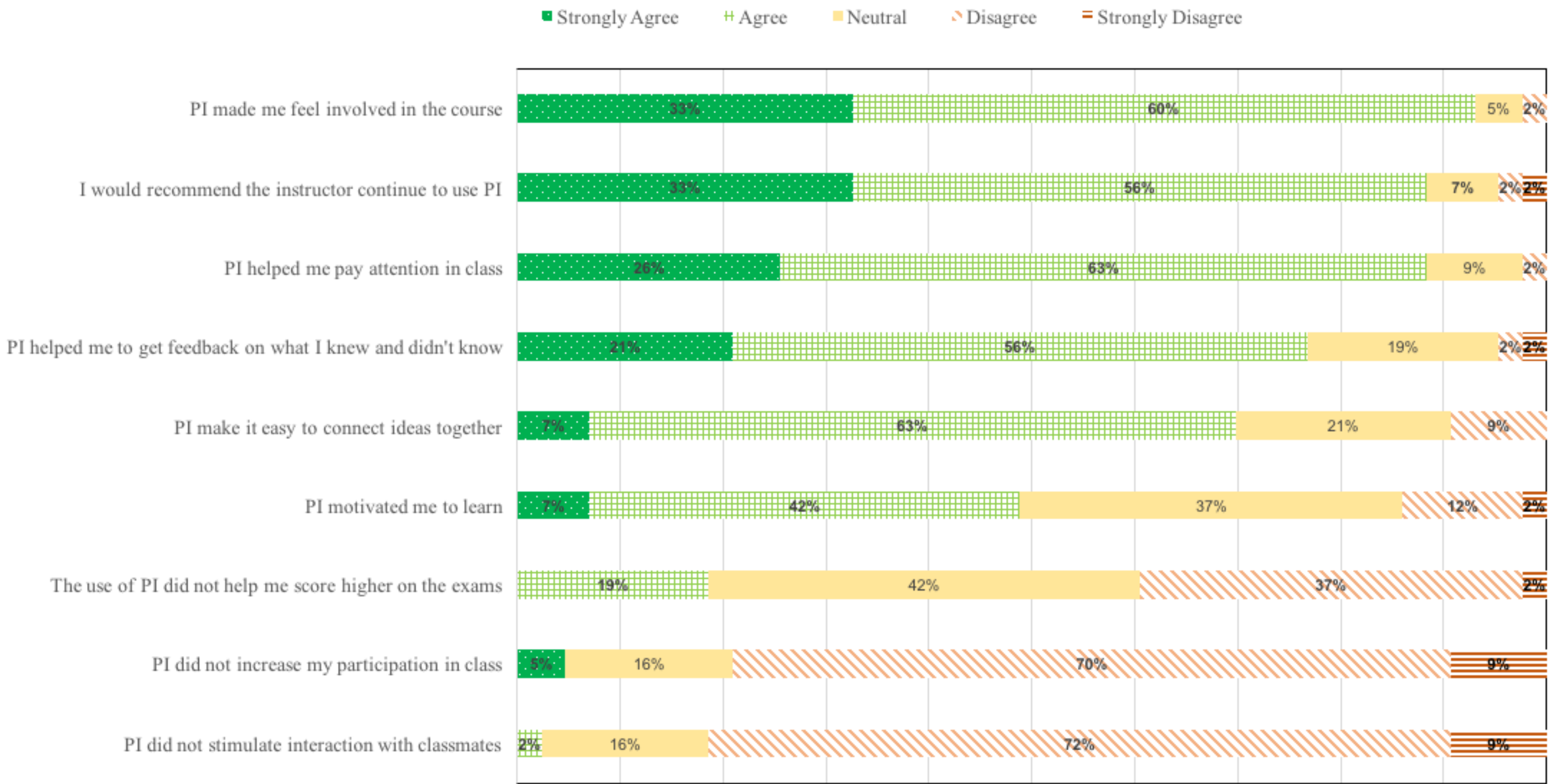

Figure 4. Results of student satisfaction survey on Peer Instruction in the environmental engineering course (n=43).

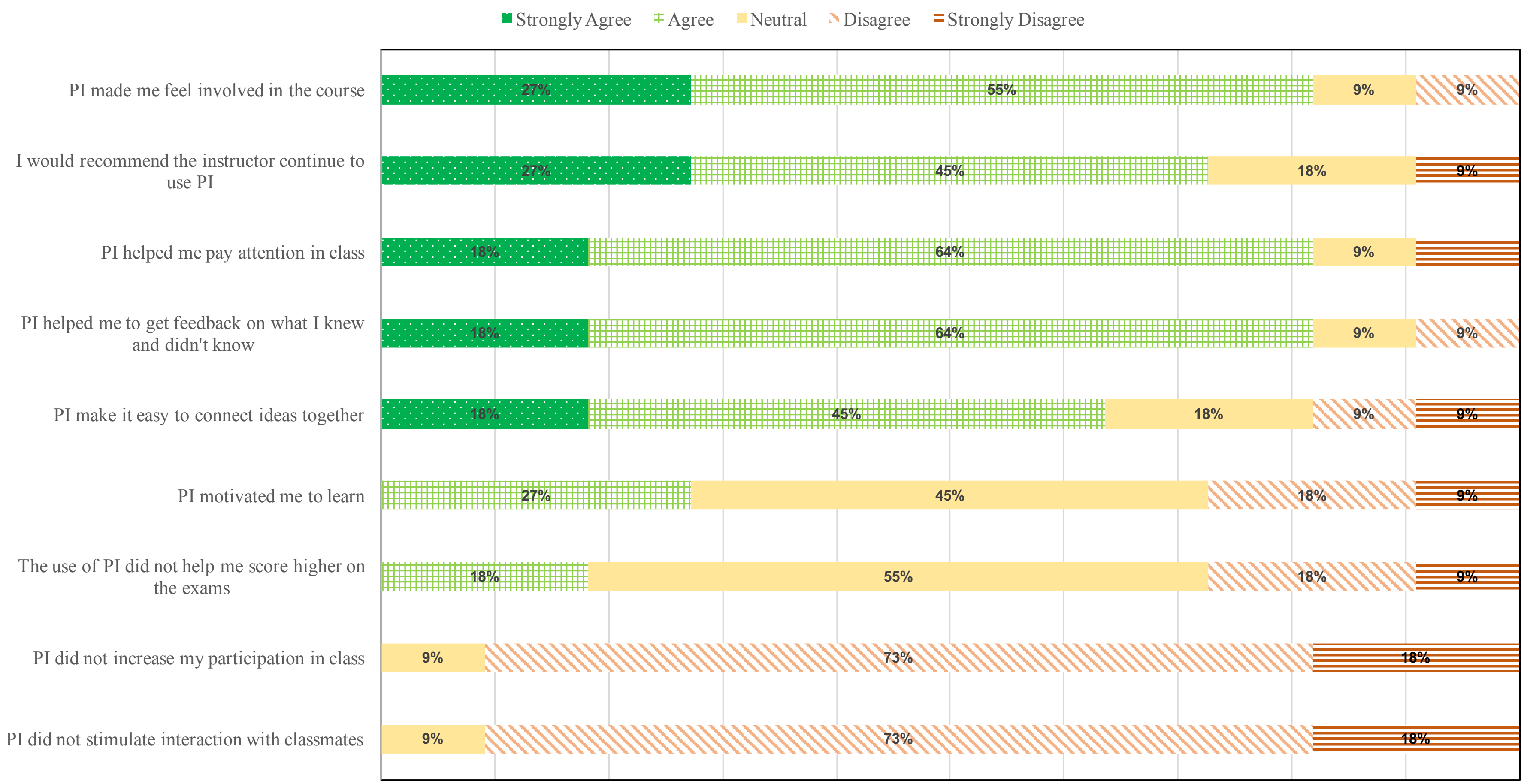

Figure 5. Results of student satisfaction survey on Peer Instruction in the structural engineering course (n=11).

Discussion and Conclusions

The preliminary results from this study highlight the utility of PI in civil engineering education. Results from the study survey indicate a strong positive response to the use of PI. 93% and 82% of the students in the environmental engineering and structural engineering courses, respectively, agreed or strongly agreed with the statement that PI made them feel more involved in the course. A majority of the students in both courses also agreed or strongly agreed that PI helped them to pay attention in class, to get feedback on what they knew and didn't know, and to connect ideas together. Most of the students disagreed or strongly disagreed with the statements that PI did not increase their participation in class or stimulate interaction with classmates. When asked whether they would recommend the instructor continue to use PI, 89% and 72% of students in the environmental engineering and structural engineering courses, respectively, agreed or strongly agreed. In both courses, many of the students reported that they had used PI in prior courses, although we did not identify whether their exposure to PI occurred in courses in the natural or physical sciences, or in prior engineering courses. Student learning outcomes associated with PI were mixed. No significant difference in learning gains was observed for the environmental engineering course. In contrast, a significant difference in learning gains was observed for the structural engineering course (along with a large effect size). These results should be considered preliminary, as the student population sizes are relatively low (n = 11 and 43). COPUS data was collected from both courses during the Fall 2017 semester, but results from this analysis are not yet available. Taken together, we believe these data indicate that PI is a technique that can be utilized in civil engineering education to increase student engagement during class, increase engagement of students with their classmates, and which may result in learning gains compared to information presented without the use of PI. A majority of students surveyed recommend the continued use of PI in engineering education.

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