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Work in Progress: Incentivizing Independent Study in Engineering Mechanics Courses

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Abstract

Students often find it tempting and expedient to rely on input from outside sources to complete homework problems which, unfortunately, bypasses the type of engagement required for real learning. Current brain science informs us of the importance of the retrieval process and spaced repetition. When students passively observe others solving problems, or merely re-copy lecture notes and solutions, they are not engaging in the necessary retrieval process for their learning to enter long-term memory. And, when students do six to eight hours of homework just one night a week, they know they are exerting a lot of effort, but may not realize their study practices don't provide the necessary spacing to cement new connections in their brains.

One obstacle in moving to better study practices is that students may believe they are learning based on the sheer magnitude of their efforts and the homework points in their teacher's grade book. The goal of this work in progress is to incentivize more frequent touches with the course content and to raise the students' awareness of what they are learning. Short, frequent digital quizzes is the solution explored in this work.

Students in a statics section submit a mix of digital or written homework each day that the class meets. On the days that digital homework is due, the class class period begins with a five-minute digital Progress Check Quiz (PCQ). PCQs consist of 1-2 simple conceptual questions or calculations related to their assignment. The PCQ gives feedback to the student on their learning and provides another opportunity for spaced retrieval related to the new concept. The quizzes are graded, but low-stake. Points lost on PCQs may be made up by completing optional "extra credit" problems in their digital assignments, thereby encouraging more practice for those who have not yet mastered the concepts. The instructor sees the the PCQ scores in real time and can revisit concepts with the class at the completion of the quiz or counsel students who are regularly not performing well.

Two surveys, one mid-semester and one at the end of the course, allow the students to report on their study practices and what actions, if any, they take in response to losing points on a Progress Check Quiz. The hope is that the introduction of PCQs incentivizes changes to behavior that improve quiz performance and deepen learning.

Preliminary results show the activities students engage with outside of the classroom are strongly tied point values. Most students report that the quizzes motivated some level of additional engagement (thinking about the content, following up with questions, or working additional problems). In general, students had positive view of the quizzes and the format.

Introduction

The perennial challenge of all instructors is to motivate their students to engage in practices outside the classroom that will increase their learning. Since the late-1800s when Ebbinghaus [1]

first discovered a link between spaced retrieval and memory, studies have confirmed and expanded on the importance of spacing out touch points with new content to create more lasting connections in our brains. (See [2] [3] for reviews.) Sleep and rest between study sessions are important for consolidating encoded memories [4] [5]. The best learning will occur if students study material multiple times throughout the week.

In addition, the form of regular touch points matters. Quizzing is better than re-reading [6] because the act of retrieval is what strengthens memory. More study time does not necessarily result in better outcomes [7] when it is concentrated into one long session. Struggling through problems is more beneficial than watching someone else work them [8] because patterns and mistakes that are observed stay in the working memory for a short while only to be swept out later. While engaging in the retrieval process (struggling through problem solving) helps move the observations into long term memory.

One way to motivate spaced retrieval in engineering mechanics courses is to assign daily homework (i.e., homework due each day the class meets), but with unlimited access to the internet, students are quite expert at finding ways to avoid the hard work of engaging in the retrieval process. Students are prone to use "learning tools" like Chegg to copy down solutions so that they might complete homework quickly and then cram the night before exams [9] [10]. Cramming may appear beneficial for immediate memory assessment but is less effective at promoting long term memory consolidation [11].

The use of more frequent quizzes can be incentive for students to do the hard work of retrieval more often, and there are many proponents of quiz-only formats [12] [13] [14] [15] [6] [16]. However, Mawhinney et al. [17] found that weekly quizzes promote concentrated study the day before the quiz, and only daily quizzes promote consistent daily study. Daily quizzes incentivize keeping up [18] and marginal students in particular may benefit [19].

Homework may still be a necessary tool to promote independent study outside the classroom. Allen et al. [12] compared multiple weekly quiz-only and homework-only sections of sophomore engineering courses and observed stronger exam averages in the quiz-only sections. However, their hybrid statics section (quizzes and homework) had the highest exam averages of all sections in the study. In Hylton and Funke's study of mastery-based formats [20], students' commitment to daily homework was highly correlated with the final grade --although they are not certain the relationship is causal.

Eliminating homework altogether may balance out the additional work involved with grading more frequent quizzes [19] but giving more quizzes also disrupts how times is spent in the classroom, because without homework, at least some of the quizzes would need to be long enough to test the students' ability to handle more complex and involved scenarios, and that takes time away from other classroom activities. Regular 20- or 30-minute quizzes can be logistically difficult to administer. A significant percentage of students have disability accommodation which could require extra time or testing in another location. That is difficult to provide when you need the student in the classroom for activities and instruction immediately

before or after the quiz. Furthermore, the time it takes to grade quizzes creates an undesirable delay in providing feedback.

A mix of daily homework (with flexible deadlines and options for extra credit) combined with daily check-ins at the start of class is explored in this work to encourage students to adjust their independent study as needed. The check-ins come in the form of self-graded assignments (similar to Badir [21]) or digital quizzes which provide immediate feedback. Since the quizzes are designed to take 1-2 minutes (and 5 minutes is allotted) all students are able to complete them in the classroom.

The proposed format is not strictly mastery-based like Hylton and Funke [20] or Lingwall and Surovek [22]. However, students are encouraged to learn from their mistakes, do additional independent work if they haven't mastered content, and importantly, engage with the material daily. The digital quizzes themselves offer two more opportunities each week for the student to engage in the retrieval process.

Methods

In this work in progress, the first research questions we sought to answer were: what activities are students engaging in when they study? does the feedback from short digital concept quizzes incentivize additional or different types of study? and what are the students' attitudes and feelings toward the quizzes? The assessment was based on student surveys.

Two Fall 2024 statics sections at the University of St. Thomas were the subjects of the study. The course met three times a week for 65 minutes and assignments were due for each class meeting except for on exam days. Two assignments each week were digital. Digital assignments were delivered through Mastering Engineering (Pearson) and included 2-4 required problems, 1-2 extra credit problems, and 1-2 zero-credit practice problems. The third assignment was a written problem set of 2-3 problems. Written assignments required professional communication of the problem and solution development. Practice problems were also suggested with the written assignments, but there was no formal submission of those problems.

Students were allowed to submit responses to digital assignments as many times as they'd like. Full credit was given for correct digital responses submitted up until the deadline. A penalty of 20% for each day late was applied for responses submitted after the deadline. Students could complete extra credit problems before or after the deadline, but the same late penalties applied. Extra credit problems were given a lower point value than the required problems.

The first five minuts of each class period was dedicated to homework feedback. On days digital assignments were due, students took a digital Progress Check Quiz (PCQ) on their phones via Canvas (our learning management system). The quizzes were generally conceptual or required minimal computation and could be easily completed in 30-60 seconds by students who knew the content well. Students were given other work to silently prepare for the lecture when they finished the quiz. The instructor could monitor scores coming into Canvas and start lecture when all students had submitted their responses. If the scores were particularly low, the instructor

could project the quiz on the screen and review the concepts. Digital assignment scores and PCQ scores were combined to represent 15% of the course grade. Extra credit points from Mastering could make up for lost points on PCQs. Although some students earned as much as 110% by the end of the semester, the category was capped at 100% at the time of grade computation.

On days written assignments were due, students self-graded of one of the problems. The solution was displayed in the classroom, and students were instructed to deduct points if they had not included essential elements like problem statements, figures, free-body diagrams, governing equations, and units. If the student had an incorrect final answer, they lost 30%. However, they were able to regain those points by entering a brief discription of what they needed to do to correct their response into Canvas. A teaching assistant reviewed the self-graded assignments, checked for completion of the second problem, alerted students to mistakes, and recorded scores in Canvas. Written homework scores were combined with project scores and made up 15% of the grade. Late written homework was only accepted under special circumstances.

The remaining 70% of their course grade came from their written exams and quiz scores. There was one 30-minute quiz, three 65-minute exames, and one 120-minute final.

Surveys were conducted during class on week 7 (survey 1) and week 15 (survey 2). Students were asked to share how they studied/pepared for the class, how they responded to losing points on a Progree Check Quiz, and how they felt about PCQs. Each section of the survey included a series of responses on a likert scale and one free response question.

Intially the number of students in the two sections combined was 49. Three students withdrew before the term ended. Thirty three of the remaining 46 students consented to participate in the study. Of those 33, 30 had completed survey 1, and 33 had completed survey 2. While the number of participants is small, the data provides some interesting initial feedback on how students are studying and what their attitudes are regarding Progress Check Quizzes.

Findings

Survey results were helpful in understanding students' practices and attitudes. Survey 1 and Survey 2 displayed similar trends. Since Survey 2 had more respondents, tables in this document are drawn from Survey 2, while student comments from both surveys are included.

1) Student Engagement with Activities Outside of Class

Figure 1 shows students were more inclined to engage in activities outside of class if the activities earned them points. The vast majority, 97%, report working the required homework problems always or usually, compared to 61% for extra credit, and 18% for text book example problems. Eighty-five percent acknowledged using some online help, but only one responded, "always." The use of online help may be under-reported. Data available from the Mastering platform shows a number of poor performing students from the class were completing the digital assignements with 100% accuracy in a shorter amount of time than their higher performing

peers. Overall there is a clear trend that assigning points to an activity outside of class does increase student engagement with it.

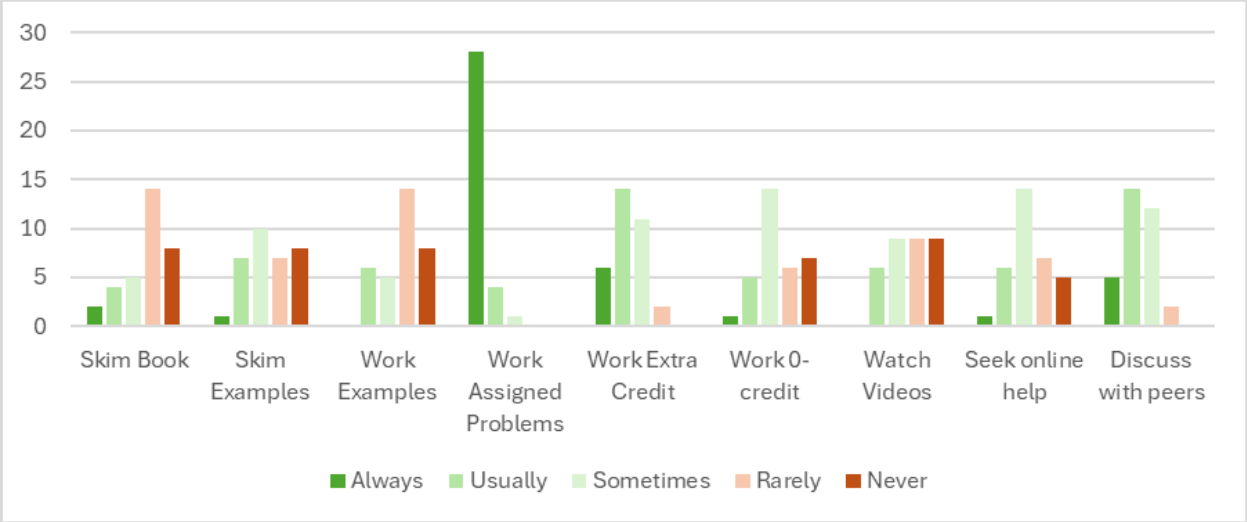

Figure 1: Survey Responses Regarding Study/Preparation Outside of Class

2) Student Response to Progress Check Quizzes

A key question to consider in this work is do the Progress Check Quizzes influence the students' behavior? Students were asked to indicate how they respond when they make a mistake on a PCQ. Respondents indicated how frequently they engaged in each activity (see Figure 2). One respondent had perfect PCQ scores over the entire semester, and therefore, percentages given in this summary are out of the 32 respondents who had non-perfect scores. Zero students indicated that they "always" take action after making a mistake, but most (96%) reported they usually or sometimes "use the quiz feedback to understand what I did wrong on my own." Eighty-eight percent usually or sometimes "ask a friend for help understanding what I did wrong." More than half (62%) report that they usually or sometimes "go back and do more Mastering problems." A smaller portion of the respondents (31%) report that they usually or sometimes "don't do anything."

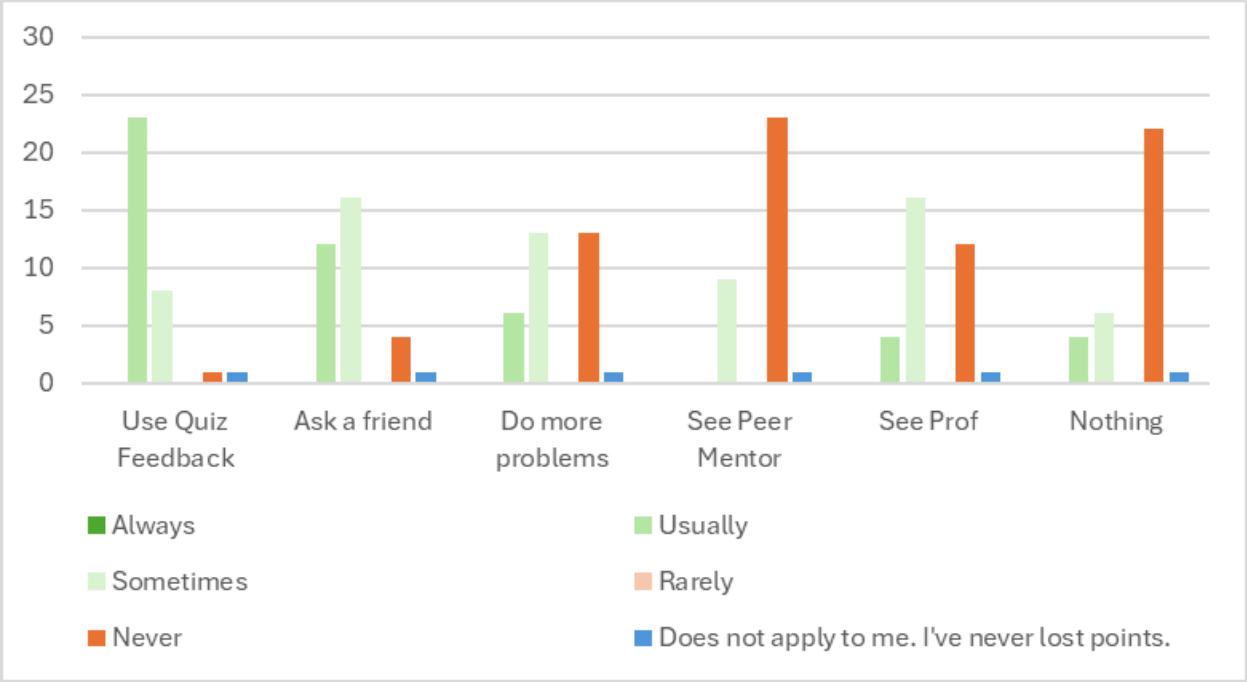

Figure 2: Actions Taken in Response to Mistakes on PCQs

When asked "Do you think Progress Check Quizzes have influenced the way that you study for this class? Please, explain," most (60%) of the students said yes, see Figure 3. One student explained, "They have helped me make sure that I think about the conceptual meaning of the subject instead of just plugging and chugging and going autopilot with the calculations." Another said, "Yes, it gives you feedback right away, either you are doing everything right, or you need to work a little bit more on that topic."

One respondent brings up a dimension the researcher had not considered in saying, "Yes, I think they tend to make me a little too confident at times." The PCQs were designed to confirm that the students have basic conceptual understanding of the course content, and that does not guarantee they can work longer computational problems in an exam format. The instructor will discuss the role of PCQ questions vs. exam questions in future sections.

Some students responded "no, but…" They said, no, the PCQs did not influence the way they study, but went on to explain some of the benefits of PCQs. For example, a student wrote "Probably not the way that I study but more so just to take a step back and see what I'm missing from the section we just learned and such." Additionally, responses labeled "no" in *Figure 3* were sometimes an indication that the student already had good study practices in place. One student said, "Not really. I think you get a good understanding of where you are at based on the written and the mastering, and if you are unable to complete those on your own or have difficulty doing so, you'll know where you're at."

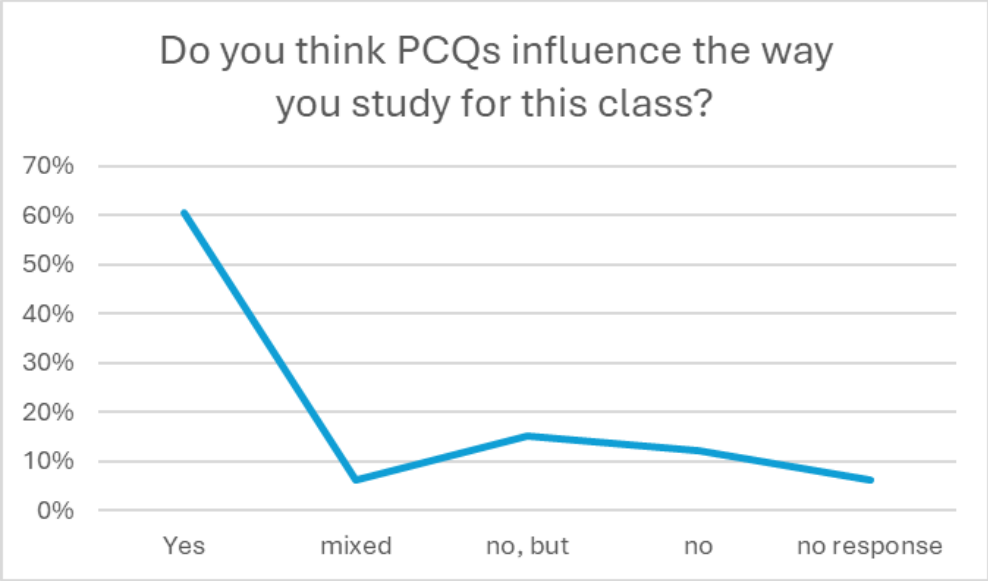

Figure 3: Free Response Regarding Influence of Progress Check Quizzes

3) Student Atttitudes Toward Progress Check Quizzes

One concern the author had was that the quizzes not be a burden or demoralizing to the students. The final section of the survey asked students to respond to more overarching statements regarding PCQs and how they were used in the class. Positive and negative statements were intermingled in the survey, but they are separated in the summary charts (Figure 4 and Figure *5*). The responses show very little negative reaction to the Progress Check Quizzes. When invited to comment overall on how the course was going, students shared some of their personal struggles and worries, but the only negative comment related to course format was that one of our units was very short which made the exam feel "crammed" to that student. Postive comments included things like, "The layout of this class made learning easy," and "There is a lot of opportunity given to succeed in this course."

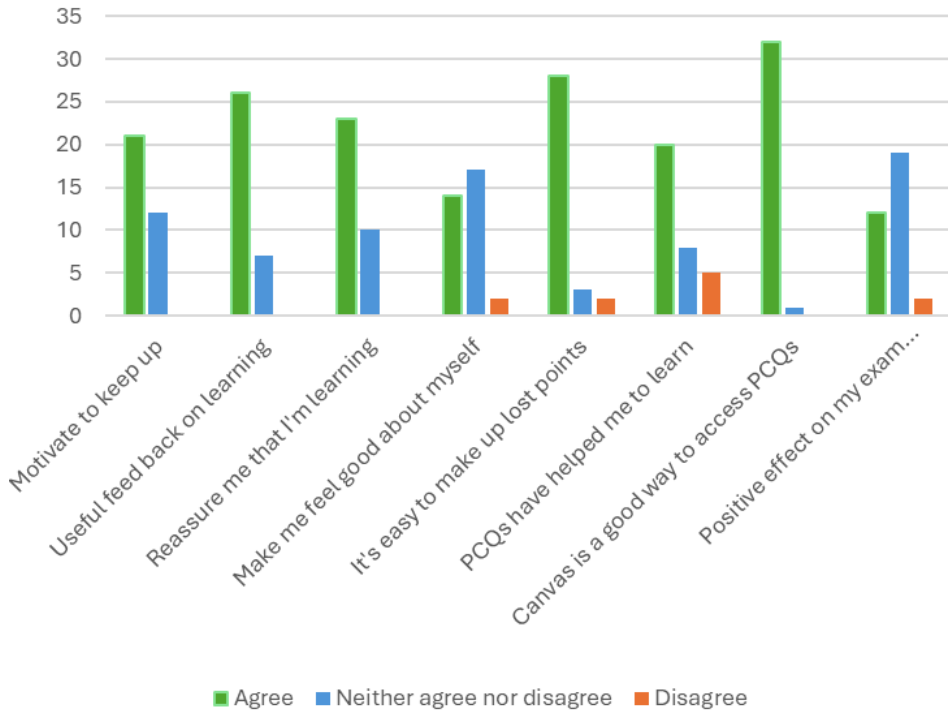

Figure 4: Agreement with Positive Statements about PCQs

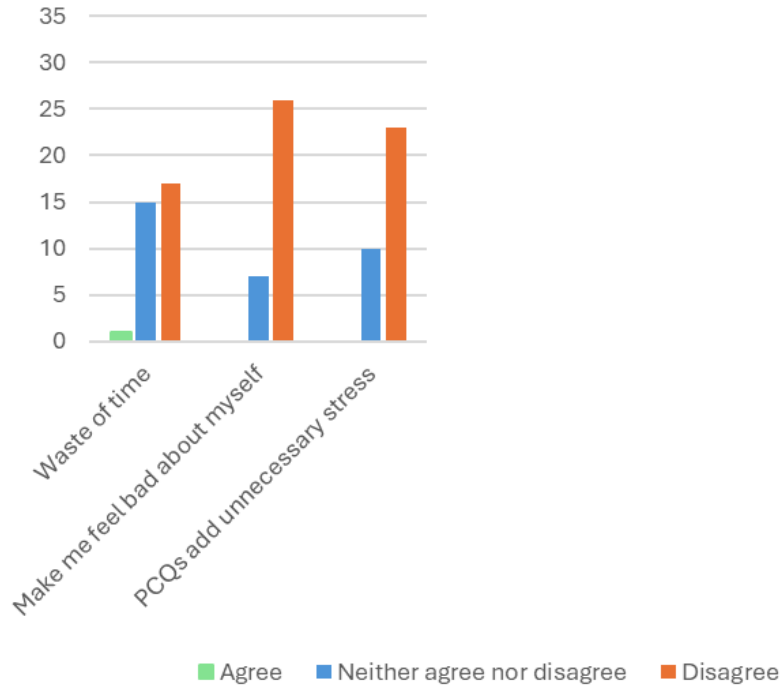

Figure 5: Agreement with Negative Statements About PCQs

Conclusions

The course format presented in this paper includes a significant amount of digital work that is collected and scored without the instructor's input. This can be a negative if it allows students to copy work and become complacent about how much they are learning in the process. The addition of 5-minute digital Progress Check Quizzes taken in-class twice a week allows both the instructor and student to get an indication of what the student is learning, and builds in additional opportunities for students to engage in the retrieval process. The use of Canvas quizzes allows the instructor to set up all the quizzes ahead of times, and while the instructor can monitor the scores in real time, no intervention is required by instructor to recorde results. Therefore, the format can be applied equally well to very small or very large sections.

The preliminary data reveals that students are motivated by points when it comes to activites outside of class. Although we can instruct students that working problems more frequently will improve their test scores, with many competing priorities it's easy for students to put off practice until right before an exam. Using more frequent quizzes helps to mitigate that problem, but longer quizzes present larger logistical challenges. Furthermore, even weekly quizzes allow students to focus most of their study to the night before the quiz, and does not encourage the necessary space retrieval for learning. Therefore, daily quizzes and daily homework is an important element of this class format.

Preliminary data shows that 5-minute digital Progress Check Quisses did impact some students' study habits, and in general, students have a positive view of their use. Even though some students were not motivated by PCQs to change their study practices, the PCQs do increase the students' engagement with the retrieval process. Each quiz that they take requires them to recall and re-engage with the content they are learning inside and outside of the classroom.

The combination of PCQs and self-graded assignments, allows the student to get feedback from every class period, and the point structure is designed for the students to continue to strive for learning, even if they did not succeed on their first try. Students have the option to go back and practice more problems for additional points if a PCQ goes poorly. They can also regain points on written work by describing the corrections that need to be made. These two elements encourage students to learn from their mistakes, and shift the focus from rewarding students for "correct answers" to a growth mindest. (Note: The course also includes computational project work in which accuracy of the students' results are emphasized.)

With only 33 participants in the study, one cannot draw too strong of conclusions, but the concept of incentivizing independent study through PCQs seems worthy of continued study. Future work will include more sections and additional mechanics courses (dynamics and deformable bodies). Additional questions which could be explored with more data include: Do PCQs improve exam performance? Are the point values on the PCQs (in relation to other work) high enough to incentivize preparation for the quizzes? Would increasing point values on PCQs have a positive or negative effect on students' independent study practices and attitudes? For some of these questions, control sections would be needed, which poses additional challenges.

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