DOES THE TIMING OF UNANNOUNCED QUIZZES INFLUENCE STUDENT BEHAVIOR IN EFFORT INVESTMENT AND LEARNING OUTPUT?

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Abstract

The main purpose of this research is to verify whether the timing of unannounced-quizzes would influence students’ behavior in effort investment and learning output. Findings suggested that: (1) students’ in-class effort was the same whether pop-quizzes were held at the beginning or end of the class; while students studied harder outside the classroom in the beginning-of-class pop-quiz system than in the end-of-class pop quiz system; (2) students’ learning output was slightly better at the beginning of the system; (3) the mixed pop-quiz system was better than the other two systems in improving students’ efforts and learning outputs; and (4) daily lateness was lower in the beginning-of-class pop-quiz system than in the end-of-class pop-quiz system. However, early departures were lower in the end-of-class pop-quiz system than in the beginning-of-class pop-quiz system. A comparison of these three systems indicated that the mixed pop-quiz system lowered late class arrivals and early departures.

Keywords: Unannounced quiz; In-class effort; Out-of-class effort; Learning output

JEL codes: A20; A22; I20; I23; C30

1. Introduction

Quizzes have been shown by numerous researchers (e.g., Turney, 1931; Geist and Soehren, 1997; Graham, 1999; Landrum, 2007; Kamuche, 2005 and 2007; Azorlosa, 2011 and 2012) to be one of the most effective pedagogical methods and have been used by many instructors to improve both their teaching and students’ learning.

While quizzes may be announced or unannounced, here we focus on unannounced quizzes (i.e., pop quizzes). This is because unannounced quizzes introduce uncertainty into the classroom experience (students are not aware in advance of the number and timing of quizzes). A study done by Lin (2013) showed that some students may behave like producers who focus on their cost/benefit. Since unannounced quizzes make students feel uncertain and hence raise the opportunity cost of missing classes, to reduce cost, students in the unannounced quiz system may choose to attend class more frequently in order to minimize grade loss from uncertainty.

However, unannounced quizzes can be held at the end or beginning of the class. If unannounced quizzes are held at the end of the class, the material on the quiz will be based on the day’s lecture. If unannounced quizzes are held at the beginning of the class, the material on the quiz will be based on the prior day’s lecture. Thus, the practice of having pop quizzes at the end of the class may lead students to invest less out-of-class effort on reviewing the prior lecture before attending the next lecture, and some students may be late more frequently. On the other hand, pop quizzes at the beginning of class may lead students to invest less in-class effort on the day’s lecture, and some may leave class early more often. Therefore, an

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6 pop quiz is something quite common in U.S. schools. It is a short test given to students without prior warning or announcement.
interesting question may be raised for investigation: would the timing of unannounced quizzes influence students’ behavior in effort investment and learning output?

Although the topic of quizzes has been widely studied by a number of researchers (e.g., Azorlosa and Renner, 2006; Wilder, Flood, and Stromsnes, 2001), it has not been broadly investigated. A similar study related to this research was done by Olson (2005), but his quizzes were announced in advance and held on the Web rather than in the classroom, which differed from our study. Consequently, the main objective of this research is to verify whether the timing of unannounced quizzes would influence students’ behavior in effort investment and learning output.

To examine this issue, we designed an experiment in which a semester was divided into three periods: (1) pop quizzes at the end of class (end-of-class pop quiz system); (2) pop quizzes at the beginning of class (beginning-of-class pop quiz system); and (3) pop quizzes at both the end and/or beginning of class (mixed pop quiz system). We also developed four research questions for this study:

(1) Will students study harder outside the classroom when pop quizzes are held at the beginning of the class than when pop quizzes are held at the end of the class even though their attendance behavior may be indifferent between these two pop quiz systems?

(2) Will students’ learning outputs (identified by exam performance) be better when pop quizzes are held at the beginning of the class than when pop quizzes are held at the end of the class?

(3) Will the mixed pop quiz system be better than the other two pop quiz systems in improving students’ efforts (in-class or/and out-of-class) and learning outputs?

(4) Will the beginning pop quiz system have a relatively lower daily rate of being late while the ending pop quiz system has a relatively lower rate of leaving early? Comparing with the above two pop quiz systems, will the mixed pop quiz system have both advantages in relatively lower daily rates of being late and leaving early?

2. Literature review

As mentioned earlier, Olson (2005) undertook a study similar to ours. However, he focused on announced quizzes held on the Web rather than in the classroom. Even though his study differed from ours, he found that quiz timing and lecture comprehension were related. He concluded that in classes with announced quizzes, students who read the textbook prior to attending lectures tended to understand the lecture better than students who did not complete the reading assignments prior to attending the lecture.

In addition to Olson (2005), a vast number of previous studies relate to the topic of quizzes although they are not directly related to our topic. Therefore, in this section, we also provide a brief look at that prior literature.

According to previous studies, not all evidence supports the use of quizzes to improve exam performance. Numerous researchers have been unable to find a significant relationship between quizzes and exam performance, including Lumsden (1976), Conard, Spenser, and Semb (1978), Beaulieu and Utecht (1987), Beaulieu and Frost (1989), Wilder, Flood, and Stromsnes (2001), Gurung (2003), and Azorlosa and Renner (2006). In addition, work by Galizzi (2010) did not support the belief that multiple-choice quizzes are a useful tool in students’ learning. Daniel and Broida (2004) compared on-line quizzes with written quizzes, and found that on-line quizzes did not improve exam performance compared to written quizzes. After some adjustment, however, they reported that both Web-based and in-class quizzes exerted a
positive effect on exam performance. Moreover, utilizing a quiz format that differs from the exam format could have an insignificant effect on exam performance. Azorlosa and Renner (2006) found that multiple-choice quizzes had no effect on essay exam performance. Therefore, in 2011 Azorlosa used the same format (multiple-choice) for both quizzes and exams, and found that quizzes had a positive effect on exam performance.

Although some previous studies did not uncover positive and significant evidence, a number did support the use of quizzes to enhance exam performance. Empirical evidence from these studies shows that quizzes (announced or unannounced) may have several instructional purposes, such as: (1) enhancing students’ attendance (e.g., Hovell, Williams and Semb, 1979; Wilder, Flood, and Stromnes, 2001; Azorlosa and Renner, 2006; Azorlosa, 2011 and 2012; Braun and Sellers, 2012), (2) increasing students’ participation (e.g., Braun and Sellers, 2012), (3) augmenting students’ preparation prior to an exam (e.g., Rusico, 2001; Marchant, 2002; Azorlosa and Renner, 2006; Azorlosa, 2011 and 2012; Braun and Sellers, 2012), (4) acting as an effective feedback mechanism (e.g., Metha, 1995; Bell, 1996), and (5) improving students’ exam performance (e.g., Turney, 1931; Geist and Soehren, 1997; Graham, 1999; Landrum, 2007; Kamuche, 2005 and 2007; Azorlosa, 2011 and 2012). Below, we briefly present selected studies relating to these five objectives.

2.1. Enhancing students’ attendance

Researchers, such as Hovell, Williams, and Semb (1979) and Braun and Sellers (2012), have discovered a positive relationship between frequent grade-related contingencies (i.e., quizzes) and high attendance, implying that attendance has been much higher on the occasion of quiz meetings rather than non-quiz meetings. In addition, even though quizzes have just been used as a reinforcement-based approach (i.e., quizzes with extra credits), quizzes still could increase lecture attendance. For example, Wilder, Flood, and Stromnes (2001) demonstrated that the use of a positive reinforcement-based approach did enhance lecture attendance by approximately 10%, implying that quizzes increased and promoted student class attendance.

Moreover, although Azorlosa and Renner (2006) did not find a significant relationship between quizzes and exam performance, they did find a significant relationship between announced multiple-choice quizzes and attendance. Like Azorlosa and Renner (2006), Azorlosa (2011) also found that quizzes significantly increased student attendance. In 2012, Azorlosa modified his 2006 and 2011 procedures, splitting students into two sections: (1) lecture section— quizzes were based on material presented during classroom lectures, and (2) textbook section— quizzes were based on material not yet covered during classroom lectures. According to the results, attendance increased in the lecture section but decreased in the textbook section.

2.2. Increasing students’ participation

As we know, learning can be enhanced through the use of small group discussion and experiential learning activities but requires students’ participation. Braun and Sellers (2012) also examined whether using a daily motivational quiz could motivate student participation in group discussions. According to their empirical evidence from a survey, 71% of the students reported being better able to participate in classroom activities and discussions, implying that the daily quiz was a significant motivator for participating in group discussions and classroom activities.
2.3. Augmenting students’ preparation prior to an exam

On many college campuses students rarely read textbooks. Vafeas (2013) showed that students’ textbook-based reading assignments are rarely completed and their completion is even lower than teacher expectations. Even though students read the book, they do not read the book until right before an exam. Therefore, can quizzes increase student reading prior to an exam? Experimental evidence from Ruscio (2001) and Marchant (2002) demonstrated that the randomly administered quiz technique significantly increased students’ engagement in assigned reading.

Ruscio (2001) developed a method in which, at the beginning of each class section, a volunteer from the class flipped a coin to determine whether there would be a quiz on that day. Questions on each quiz were drawn from the assigned reading. To receive full credit for the quiz, students had to prove that they had really devoted effort to reading. Marchant (2002) assigned articles to students who were provided with one of three messages by the instructor: (1) a quiz in class; (2) just for professional benefit; or (3) only for class discussions. On a survey, students reported that they would read articles more thoroughly if preparing for a quiz than for the other two purposes.

In addition, survey results from the study by Azorlosa and Renner (2006) showed that students who were in the quiz section studied a few more hours a week than students who were in the no-quiz section. Similarly, Azorlosa (2011) also reported that most of the students in the quiz sections agreed that quizzes did increase their studying time each week. Azorlosa (2012) further showed that the vast majority of students believed that quizzes assisted them in preparing for the exam and enhanced their studying time each week. Furthermore, in a survey study by Braun and Sellers (2012) also showed that 73% believed the daily quiz was the primary reason for their preparation. In short, these studies all demonstrated that quizzes increased reading prior to an exam.

2.4. Acting as an effective feedback mechanism

Students’ instant feedback is very important to instructors because it shows them how much students have learned. Quizzes may be a good method for obtaining students’ instant feedback. Metha (1995) found that quizzes provided instructors with instant responses from all students, because the instant assessment of student learning gave instructors information needed to take any corrective measures. Similarly, Bell (1996) also demonstrated that quizzes were an effective technique for obtaining instant feedback and assessing student learning.

2.5. Improving students’ learning outcome

Improving students’ learning and understanding of the material is the most important instructional objective. The earliest study on this topic is believed to be that by Turney (1931), who split students into two groups in an educational psychology class: (1) the experimental group was given weekly quizzes and exams, and (2) the control group was given only exams. Turney concluded that frequency of testing (e.g., weekly quizzes) motivated students to attend class more frequently and study a few more hours and hence improved their learning outcomes. In 1997, Geist and Soehren also reached a similar conclusion. They investigated the relationship between frequent quizzes and short- and long-term academic performance in an introductory radiology course. They found that while frequent quizzes enhanced students’ short-term performance on examinations, the impacts of long-term retention of knowledge did not seem to be significant.

In addition, researchers were interested in learning who would benefit the most from quizzes. Graham (1999) found an answer. His results showed that test scores in the classes with quizzes were significantly higher than test scores in the classes without quizzes; students in the mid-range (C grade) benefitted the most from quizzes. Moreover, most instructors do not allow
students who miss a quiz to take a make-up quiz. However, if a make-up quiz is allowed, what is the effect? Landrum (2007) showed that students who took make-up quizzes scored much higher than those taking in-class quizzes and also performed better on the cumulative final exam.

Furthermore, would different types of quizzes have different effects on students’ exam performance? Although Kamuche (2005) showed that students in the weekly-quiz group performed better on exams than students in the no-quiz group, Kamuche in 2007 further explored the effect of announced and unannounced quizzes on students’ exam performance. He found that both announced and unannounced quizzes improved students’ exam performance, but students who took unannounced quizzes performed better than students who took announced quizzes.

Finally, would the format of quiz and exam influence outcomes? As described earlier in this section, Azorlosa and Renner (2006) used different formats for quizzes and exams and found that multiple-choice quizzes had no effect on essay exam performance. Therefore, Azorlosa (2011) used the same format (multiple-choice tests) for both quizzes and exams and found that quizzes significantly improved student exam performance. In 2012, Azorlosa developed different quiz content for lecture and textbook groups and found that exam scores improved for both groups but were slightly better in the lecture group than in the textbook group. Azorlosa concluded that this effect was not due to increased textbook reading between exams, but to the benefits of taking quizzes, which helped students to practice answering multiple-choice questions (since both quizzes and exams had the same format regardless of content).

3. Method
3.1 Experimental design

Sixty-seven students in Introduction to Microeconomics class in fall 2015 participated in this experiment. The course grade was based upon three exams (Exam 1, Exam 2, and Exam 3) and several pop quizzes. The semester was split into three periods. Period 1 extended from the first to the fifth week of the semester (Exam 1 was held in the end of Period 1); Period 2, from the sixth to the tenth week of the semester (Exam 2 was held at the end of Period 2); and Period 3, the eleventh to the fifteenth week of the semester (Exam 3 was held at the end of Period 3).

Each exam weighted 25% of the course grade and was graded on a 100-point scale. Exam 3 was the final exam, but it was not comprehensive. All quizzes weighted 25% of the course grade. However, the time schedule for and material covered on each quiz were not provided on the syllabus. Hence, students were not aware of how many quizzes there would be during the semester and the date of each quiz in advance. Each class met twice a week. No additional weekly review/tutorial classes were provided by graduate students. Daily attendance was taken, but there was no penalty for skipping classes and no bonus for attending classes. Students were given complete freedom to choose whether or not to attend class. Participation in class discussions was encouraged but not part of the course grade.

On the first day of Period 1, the instructor told students that each quiz would begin 5–10 minutes before the end of the class. The material on the quiz would be based on the day’s lecture. The format of quizzes was short-essay and/or simple problem. Hence, students had to concentrate in class; otherwise, they were not able to answer the questions. After all students had completed each quiz, the instructor discussed the quiz right away and then students could leave. In total, there were three quizzes in the first period.

After Exam 1 and on the first day of Period 2, the instructor told students that each quiz would begin 5–10 minutes before the lecture started. The material on the quiz would be based on the prior day’s lecture. The format of quizzes was short-essay and/or simple problem.
Thus, if students did not review the prior day’s lecture, they were not able to answer the questions. After all students had completed each quiz, the instructor promptly discussed the quiz and then presented a lecture to the class. In total, there were four quizzes in the second period.

After Exam 2 and on the first day of Period 3, the instructor told students that each quiz would begin 5–10 minutes before the lecture presentation or 5–10 minutes before the end of the class, or both quizzes could be held on the same day. The material on the quiz could be based on the prior day’s lecture or based on the day’s lecture, or based on both if two quizzes were held on the same day. The format of the quizzes was short-essay and/or simple problem. Thus, if students did not review the prior day’s lecture or did not concentrate in class, they were not able to answer the questions. After all students had completed each quiz, the instructor immediately discussed the quiz and then presented a lecture to the class or students were allowed to leave if the quiz was held at the end of the class. In total, there were six quizzes in the third period. The first and second quizzes were held on the same day, and the fifth and sixth quizzes were also held on the same day. The third quiz was held at the end of the class, while the fourth quiz was held at the beginning of the class.

It should be noted that absent students were not allowed to take a make-up quiz later, no matter what their reasons for missing class. If the quiz was held at the end of class, students who left early were not allowed to take a make-up quiz later, no matter what their reasons for leaving early. Similarly, if the quiz was held at the beginning of the class, late students were not given extended time or a make-up quiz if they came after the quiz was done.

3.2 Data

The data contained instructor-reported and self-reported data. The instructor-reported data included student exam scores, attendance, GPA, total credits taken in the semester, and gender, which can be easily collected without a survey. These five variables are explained as follows:

1. Exam scores. The instructor had a record of students’ three exam scores. These exam scores could be used as a proxy for a student’s learning output. The exam scores were original exam scores without a curve. Each exam included multiple-choice and critical analysis essays and problems. Some of the critical analysis essays and problems were similar to or the same as the questions in quizzes. The instructor also controlled the difficulty for each exam at the same level.

2. Attendance (In-class effort). During the first class of the semester, the instructor gave students a sign-up seat sheet and students signed up for their preferred seats. However, if students wanted to change seats after they signed up, they had to let the instructor know and re-signed up again. Based upon the sign-up seat sheet, the instructor was able to check students’ daily attendance and note when students were late and left early. In addition, every student’s picture was posted online by the university, which helped the instructor to know every student. Moreover, students were told by the instructor that it was just for record-keeping purposes and would not affect their final grades due to no mandatory attendance policies.

3. GPA (Grade Point Average). Each student’s GPA was provided by the office of the registrar. GPA has been proven by researchers (e.g., Karsenti and Thibert, 1995; Afzal, Ali, Khan, and Hamid, 2010) to reflect a student’s motivation to learn and their quality. Lin, Yu, and Chen (2012) also demonstrated that GPA is a strong predictor of academic motivation and GPA are positively and significantly associated. Afzal, Ali, Khan, and Hamid (2010) also demonstrated that intrinsic motivation is highly correlated with GPA. In addition, GPA explains plenty of the variance in learning outcomes/final exam scores (see Bacon and Bean, 2006).
students’ academic performance and retention rate. While SAT (Scholastic Aptitude Test) scores are also a proxy of student quality widely employed by researchers (e.g., Lin and Quayes, 2006; Dynarski and Gleason, 1993), both GPA and SAT cannot coexist in a regression model. This is because these two variables are correlated, which would result in a multicollinearity problem. For that reason, GPA was used to proxy for both motivation to learn and student quality.

4. Total credits taken in the semester. Each student’s total credits taken in the semester were provided by the office of the registrar. The more credit hours taken by the student in a semester, the less time the student can study for the class. For that reason, it may reflect a student’s opportunity cost of studying for the class.

5. Gender. There is a possibility that gender maybe related to a student’s learning output and attendance behavior. The instructor identified each student’s gender. This was a dummy variable, so we set male as 1 and female as 0.

In addition, the self-reported data consisted of total work hours for pay per week, living with young kids, college algebra, college calculus, and study outside classroom. These data were collected through questionnaires. About five minutes before each exam started, a proctor came to the class to administer a survey. The instructor was not in the classroom when the survey was administered. Students were told that they had the option not to participate in the study, and that the survey did not count towards their final grade. There was no interview and no audio- or video-taping. The questionnaire was designed to take approximately 5 minutes. The questionnaire was constructed as follows:

1. Do you work for pay? Yes: ____; No: _____. If you answer “yes”, approximately, how many hours a week do you work for pay? ______

2. Do you live with young kids (below 10 years old)? Yes: ____; No: _____.

3. Have you completed college algebra? Yes: ____; No: _____.

4. Have you completed college calculus? Yes: ____; No: _____. Approximately, how long did you study for the class during the exam period? (Circle one)

   1 = I study 1–5 hours before the exam;
   2 = I study 6–10 hours before the exam;
   3 = I study 11–15 hours before the exam;
   4 = I study 16–20 hours before the exam;
   5 = I study more than 20 hours before the exam.

These five variables are explained below:

1. Total work hours for pay per week. This question was only asked once in the questionnaire at the first exam. The variable also can represent a student’s

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9 The empirical evidence may be found in Woodfield, Jessop, and McMillan (2006), Cortright, Lujan, Cox, and DiCarlo (2011), and Paise and Paise, (2004) (as cited in Lin, 2014): (1) female students attend classes more often than male students (Woodfield, Jessop, and McMillan, 2006); (2) gender may be a factor in determining the relationship between grades and attendance (Cortright, Lujan, Cox, and DiCarlo, 2011); and (3) grades and attendance are more significantly related in male students than in female students (Paise and Paise, 2004).

9 Students were not asked to report the number of hours devoted to studying for the class during the exam period because they might not exactly recall the precise number of hours and might leave it blank. Nevertheless, it might be less difficult for them to recall the extent to which they studied for the class.
opportunity cost of studying for the class. The more hours worked by the student during a semester, the less time the student can spend studying for the class.

2. Living with young kids. This question was only asked once in the questionnaire at the first exam. Young kids (below ten years of age) may need more parental attention and care. Hence, it could affect the student’s attendance and distract the student’s study. That is, it may identify both “care-giving responsibilities” and “potential distractions”. This was a dummy variable; hence, “yes” was set as 1 and “no” as 0.

3. College algebra. This question was only asked once in the questionnaire at the first exam. College algebra is an important mathematical background for learning economics. This was a dummy variable. We set “yes” as 1 and “no” as 0.

4. College calculus. This question was only asked once in the questionnaire at the first exam. College calculus background will benefit students in learning economics. This was a dummy variable. We set “yes” as 1 and “no” as 0.

5. Study outside classroom. This question was asked on each exam. This variable reflects a student’s out-of-class effort.

Moreover, we did not ask students about their motivation to learn and interest in the class, because it is more confidential. If the question was asked, some (or many) students might not honestly answer due to the lack of anonymity. GPA can proxy both a student’s motivation to learn and ability; therefore, we did not need to ask students about their motivation to learn and interest in the class.

Table 1 reports descriptive statistics. In addition, Cronbach’s alpha was 0.91, implying strong internal consistency among these exams.

3.3 Regression models and one-tailed hypothesis test

Below, we developed regression models to investigate Hypotheses 1–3, and constructed the one-tailed hypothesis test to examine Hypothesis 4.

Hypothesis 1: Students’ attendance (in-class effort) is no different whether pop quizzes are given at the beginning or end of the class; however, students will study harder outside the classroom when pop quizzes are held at the beginning of the class than when pop quizzes are held at the end of the class.

Beginning vs. Ending

\[ \begin{align*}
\text{ATD} &= \alpha_0 + \alpha_1 \text{GPA} + \alpha_2 \text{WHR} + \alpha_3 \text{CRD} + \alpha_4 \text{MAL} + \alpha_5 \text{KID} + \alpha_6 \text{POP}_B + u_1, \\
\text{STD} &= \alpha_0 + \alpha_1 \text{GPA} + \alpha_2 \text{WHR} + \alpha_3 \text{CRD} + \alpha_4 \text{MAL} + \alpha_5 \text{KID} + \alpha_6 \text{POP}_B + u_2,
\end{align*} \]

Where \( \text{ATD} = \) attendance (in-class effort); \( \text{STD} = \) out-of-class effort; \( \text{GPA} = \) Grade Point Average; \( \text{WHR} = \) total work hours for pay per week; \( \text{CRD} = \) total credits taken in the semester; \( \text{MAL} = \) male student (dummy variable); \( \text{KID} = \) living with young kids (dummy variable); \( \text{POP}_B = \) dummy variable (pop-quiz held at the beginning of the class in period 2); and \( u_1, u_2 = \) stochastic disturbance with a mean 0 and a variance \( 0^2 \).

In this formulation, the null hypothesis was that the parameters \( \alpha_6 \) and \( \alpha_6 \) were zero, while the alternative hypothesis was that the parameters \( \alpha_6 \) and \( \alpha_6 \) were not zero. That is, Hypothesis 1 was supported when \( \alpha_6 = 0 \) and \( \alpha_6 > 0 \) (and the effect of \( \alpha_6 \) should be significant).

Hypothesis 2: Students’ learning outputs are better when pop quizzes are held at the beginning of the class than when pop quizzes are held at the end of the class.

Beginning vs. Ending
EXA = $\gamma_0 + \gamma_1 ATD + \gamma_2 STD + \gamma_3 GPA + \gamma_4 WHR + \gamma_5 CRD + \gamma_6 MAL + \gamma_7 KID$

$+ \gamma_8 ALG + \gamma_9 CAL + \gamma_{10} POP_M + u_3,$  \hspace{1cm} (3)

where $EXA =$ Exam scores (learning outputs); $ALG =$ have taken college algebra class (dummy variable); $CAL =$ have taken college calculus class (dummy variable); and $u_3 =$ stochastic disturbance with a mean 0 and a variance $\zeta^2$. In this formulation, the null hypothesis was that the parameter ($\beta_{10}$) was zero, while the alternative hypothesis was that the parameter ($\beta_{10}$) was not zero. That is, Hypothesis 2 was supported when $\beta_{10}>0$ and the effect should be significant.

In this formulation, the null hypothesis was that the parameter ($\beta_{10}$) was zero, while the alternative hypothesis was that the parameter ($\beta_{10}$) was not zero. That is, Hypothesis 2 was supported when $\beta_{10}>0$ and the effect should be significant.

**Hypothesis 3**: The mixed pop quizzes system (i.e., co-existence of pop quizzes at the end and beginning of the class) is better than the other two pop quizzes systems (i.e., pop quizzes are held at the end or beginning of the class) in improving students’ efforts (in-class or/and out-of-class efforts) and learning outputs.

Mixed vs. Ending and Mixed vs. Beginning:

\[
ATD = \beta_0 + \beta_1 GPA + \beta_2 WHR + \beta_3 CRD + \beta_4 MAL + \beta_5 KID + \beta_{6} POP_M + \epsilon_1,  \hspace{1cm} (4)
\]

\[
STD = b_0 + b_1 GPA + b_2 WHR + b_3 CRD + b_4 MAL + b_5 KID + b_{6} POP_M + \epsilon_2,  \hspace{1cm} (5)
\]

\[
EXA = \lambda_0 + \lambda_1 ATD + \lambda_2 STD + \lambda_3 GPA + \lambda_4 WHR + \lambda_5 CRD + \lambda_6 MAL + \lambda_7 KID
\]

$+ \lambda_8 ALG + \lambda_9 CAL + \lambda_{10} POP_M + \epsilon_3  \hspace{1cm} (6)$

where $POPM =$ dummy variable (mixed pop-quiz held at the end or beginning of the class in Period 3); and $\epsilon_1, \epsilon_2, \epsilon_3 =$ stochastic disturbance with a mean 0 and a variance $\sigma^2$. In this formulation, the null hypothesis was that the parameters ($\beta_6, b_6, \lambda_{10}$) were zero, while the alternative hypothesis was that the parameters ($\beta_6, b_6, \lambda_{10}$) were not zero. That is, Hypothesis 3 was supported when $\beta_6, b_6, \lambda_{10}>0$ and the effects should be significant.

**Hypothesis 4**: The beginning-of-class pop quiz system has a relatively lower daily rate of late students; while the end-of-class pop quiz system has a relatively lower rate of early departure by students. Thus, compared with the above two pop quiz systems, the mixed pop quiz system has advantages in leading to relatively lower daily rates of being late and leaving early.

To verify Hypothesis 4, we adopted the one-tailed hypothesis test. The null ($H_0$) and alternative ($Ha$) hypotheses can be formulated as follows:

| Rate of being late | Mixed vs. Beginning | Mixed vs. Ending | Beginning vs. Ending |
\[
\begin{align*}
\{ \begin{align*}
H : \mu^M - \mu^B & \geq 0 & H : \mu^M - \mu^B & \geq 0 & H : \mu^M - \mu^B & \geq 0 \\
\{ | 0 & M & B \} & \{ | 0 & M & B \} & \{ | 0 & M & B \} \\
H : \mu^M - \mu^B & < 0 & H : \mu^M - \mu^B & < 0 & H : \mu^M - \mu^B & < 0 \\
\} a & M & B & \} a & M & M & \} a & M & E
\end{align*}
\]

Rate of leaving early

<table>
<thead>
<tr>
<th>Mixed vs. Beginning</th>
<th>Mixed vs. Ending</th>
<th>Beginning vs. Ending</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H : \mu^M - \mu^B \geq 0$</td>
<td>$H : \mu^B - \mu^E \geq 0$</td>
<td>$H : \mu^B - \mu^E \leq 0$</td>
</tr>
<tr>
<td>${</td>
<td>0 &amp; M &amp; B }$</td>
<td>${</td>
</tr>
<tr>
<td>$H : \mu^B - \mu^E &lt; 0$</td>
<td>$H : \mu^B - \mu^E &lt; 0$</td>
<td>$H : \mu^B - \mu^E &gt; 0$</td>
</tr>
<tr>
<td>$l a &amp; M &amp; B$</td>
<td>$l a &amp; M &amp; E$</td>
<td>$l a &amp; M &amp; E$</td>
</tr>
</tbody>
</table>

where $\mu^M$ is the population mean of daily rate of being late under the mixed pop quiz system; $\mu^B$ is the population mean of daily rate of being late when pop quizzes were held at the beginning of the class; $\mu^E$ is the population mean of daily rate of being late when pop quizzes were held at the end of the class; $\mu^M$ is the population mean of daily rate of leaving early under the mixed pop quiz system; $\mu^B$ is the population mean of daily rate of leaving early when pop quizzes were held at the beginning of the class; and $\mu^E$ is the population mean of daily rate of leaving early when pop quizzes were held at the end of the class.

4. Results

4.1. Hypothesis 1

The results for Equations (1) and (2) for “Beginning vs. Ending” are presented in Columns 1 and 2 of Table 2. As shown there, for attendance (ATD), the null hypothesis that “pop quizzes were held at the beginning of the class” was not related to “students’ attendance behavior whether pop quizzes were held at the beginning or end of the class” was not rejected. It was because POPB (dummy variable) did not exert a statistically significant effect on ATD at any significance level (10%, 5%, or 1%) as shown in Column 1 of Table 2, implying that students’ attendance (in-class effort) behavior was the same whether pop quizzes were held at the beginning or end of class.

However, for out-of-class effort (STD), the null hypothesis that “pop quizzes were held at the beginning of the class” was not related to “students’ out-of-class effort whether pop quizzes were held at the beginning or end of the class” was rejected. It was because POPB (dummy variable) exerted a positive and statistically significant effect on STD at the 1% significance level as shown in Column 2 of Table 2, implying that students would study harder outside the classroom when pop quizzes were held at the beginning rather than the end of the class.

Consequently, Hypothesis 1 was supported. Students’ attendance (in-class effort) behavior did not significantly differ whether pop quizzes occurred at the beginning or end of the class. Nevertheless, students would study harder outside the classroom when pop quizzes were held at the beginning of the class than at the end of the class.

4.2 Hypothesis 2
The results for Equation (3) for “Beginning vs. Ending” are reported in Column 3 of Table 2. As Column 3 of Table 2 shows, for exam performance (EXA), the null hypothesis that “pop quizzes were held at the beginning of the class” was not related to “students’ exam performance whether pop quizzes were held at the beginning or at the end of the class” was not rejected. It was because POPB (dummy variable) did not exert a statistically significant effect on EXA at any significance level (10%, 5%, or 1%) as shown in Column 3 of Table 2 (although the coefficient is positive), implying that students’ exam performance (learning output) was not significantly different between pop quizzes at the beginning or end of the class. This result did not sustain our initial hypothesis. Therefore, Hypothesis 2 was not supported.

4.3 Hypothesis 3

The results for Equations (4), (5), and (6) for “Mixed vs. Ending” and “Mixed vs. Beginning” are presented in Columns 4 – 9 of Table 2. As shown there, for “Mixed vs. Ending”, the null hypothesis that “co-existence of whether pop quizzes occurred at the end and the beginning of the class” is not related to “students’ attendance behavior, out-of-class effort, and exam performance whether pop quizzes were held at the end or co-existence of the class” was rejected. It was because POPM (dummy variable) provided positive and statistically significant effects on ATD, STD, and EXA at the 5%, 1%, and 1% significance levels, respectively, in Columns 4 – 6 of Table 2. These results imply that the mixed pop quizzes system (co-existence of pop quizzes at the end and beginning of the class) is better than the end-of-class system in improving students’ attendance (in-class effort), out-of-class effort, and learning outputs.

In addition, for “Mixed vs. Beginning”, the null hypothesis that “co-existence of pop quizzes at the end and beginning of the class” is not related to “students’ attendance behavior and exam performance whether pop quizzes were held at the beginning or co-existence of the class” was rejected. It was because POPM (dummy variable) offered positive and statistically significant effects on ATD and EXA at the 5% and 10% significance levels, respectively, in Columns 7 and 9 of Table 2. However, the null hypothesis that “co-existence of pop quizzes at the end and beginning of the class” is not related to “students’ out-of-class effort whether pop quizzes were held at the beginning or co-existence of the class” was not rejected. It was because POPM (dummy variable) did not exert statistically significant effects on STD at any significance level (10%, 5%, or 1%) as shown in Column 8 of Table 2.

The results displayed above indicate that the mixed pop quizzes system (co-existence of pop quizzes at the end and beginning of class) is better than the beginning-of-class system in improving students’ in-class effort and learning outputs, but not in out-of-class effort.

As a result, overall, Hypothesis 3 was supported. The mixed pop quizzes system (i.e., co-existence of pop quizzes at the end and beginning of class) is better than the other two pop quizzes systems (i.e., end or beginning of class) in improving students’ efforts (in-class or/and out-of-class efforts) and learning outputs.

4.4 Hypothesis 4

The results for the one-tailed test are reported in Table 3. As shown there, for the daily rate of being late, both the mixed pop quiz system and the beginning-of-class pop quiz system have a significantly lower daily rate of being late than the end-of-class pop quiz system. However, the daily tardiness rate was not significantly lower for the mixed pop quiz system than the beginning-of-class pop quiz system.

In addition, for the daily rate of leaving early, both the mixed pop quiz system and the end-of-class pop quiz system have a significantly lower daily rate of leaving early than the beginning-of-class pop quiz system. As a consequence, overall, Hypothesis 4 was supported. Students in classes where pop quizzes are given at the beginning of the class have a relatively
lower daily rate of being late; while those in classes where pop quizzes occur at the end of the class have a relatively lower rate of leaving early. Therefore, compared with the above two pop quiz systems, the mixed pop quiz system has advantages in offering relatively lower daily rates of being late and leaving early.

5. Discussion

Except for Hypothesis 2, the other three hypotheses were supported by our evidence. In this section, we discuss why Hypothesis 2 was not strongly supported by our evidence.

As noted earlier, the instructor had ensured that each exam had the same level of difficulty. Additionally, according to Cronbach’s alpha (0.91), there was strong internal consistency among these exams. For that reason, the difficulty for each exam may be considered as a constant, which means that our discussion will focus on students’ efforts.

Initially, we hypothesized that students’ exam performance would be significantly higher when pop quizzes were held at the beginning of the class than when pop quizzes were held at the end of the class. The reasoning was that students would invest more out-of-class effort in advance when pop quizzes were held at the beginning of class. Unfortunately, our empirical evidence did not strongly sustain that hypothesis. However, if we take a closer look at Table 1, the mean scores were a little higher for Exam 2 (73.04) than for Exam 1 (69.75), implying that students’ learning outputs indeed were improved from Exam 1 to Exam 2, although they were not significantly improved. In addition, based upon the one-tailed test for the mean scores of exams, at the 10% significance level, the population mean for exam score was higher when pop quizzes were held at the beginning than end of the class.

While the mean score for Exam 2 was higher than the mean score for Exam 1 at the 10% significance level under the one-tailed hypothesis test, we still cannot claim that students’ exam performance was significantly higher when pop quizzes were held at the beginning than end of class because it was not significant at the 5% or 1% significance levels. Hence, the question here is: why couldn’t students’ exam performance significantly improve from Exam 1 to Exam 2 since students had enhanced their out-of-class effort from Period 1 to Period 2?

There may be two possible reasons why Hypothesis 2 was not strongly supported by our empirical evidence:

(1) When quizzes were held at the end of class, students had to concentrate in class—otherwise, they would not be able to answer the questions. However, when quizzes were held at the beginning of class, students might not concentrate thereafter in class since the material on each quiz was based upon the prior day’s lecture. Students who did not concentrate in class might think that they could still get the information from the textbook. However, much of the information from instructors’ classroom lectures may not be found in textbooks or online. Therefore, even though these students might try to study hard outside the classroom, they might still lose important information and thus could not significantly improve their next exam performance.

(2) When quizzes were held at the beginning of class, students who finished the quiz might leave class early and thus miss some important information. This may explain why the daily rate of leaving early was higher in the beginning-of-class quiz system.
than the end-of-class quiz system (see Table 1). As discussed above, students may not find the missing information in textbooks or online. For that reason, students could not significantly perform better on Exam 2 than on Exam 1—they only performed slightly better.

6. Conclusion

In this paper, we developed regression models and a one-tailed hypothesis test to examine four hypotheses designed to determine whether timing of pop quizzes would influence students’ behavior in effort investment and learning output. In light of the empirical results, four major findings are offered:

(1) Students’ attendance (in-class effort) behavior did not significantly differ whether pop quizzes were held at the beginning or end of class; students studied harder outside the classroom when pop quizzes were held at the beginning of the class than when pop quizzes were held at the end of the class.

(2) Students’ exam performance (learning output) was slightly (not significantly) better when pop quizzes were held at the beginning of the class than when pop quizzes were held at the end of the class.

(3) The mixed pop quiz system (i.e., co-existence of pop quizzes at the end and beginning of the class) was better than the other two pop quiz systems (i.e., beginning- or end-of-class) in improving students’ efforts (in-class or/and out-of-class efforts) and learning outputs.

(4) The daily late arrival rate was significantly lower when pop quizzes were given at the beginning of the class than end of class. However, the daily early departure rate was significantly lower when pop quizzes occurred at the end than the beginning of class. Therefore, compared with these two pop quiz systems, the mixed pop quiz system has advantages in lowering late arrival and early departure rates.

Moreover, we further discussed why Hypothesis 2 was not strongly supported by our empirical evidence, or why students couldn’t perform significantly better on Exam 2 than on Exam 1 since students had enhanced their out-of-class effort from Period 1 to Period 2. Two possible explanations were offered: compared with the end-of-class pop quiz system, beginning-of-class pop quizzes might lead some students not to concentrate in class and to leave class early more frequently. As a result, they might miss some important information that couldn’t be found in textbooks or online.

Above all, based upon our empirical findings and discussion, we can conclude that the timing of pop quizzes does influence students’ behavior in effort investment and learning output. In addition, we suggest that the mixed pop quiz system may be a more effective pedagogical method since the mixed system may take advantage of the other two systems.

In summary, the main contribution of this study to the scholarship of teaching and learning is that we verify an important fact: timing of pop quizzes does influence students’ behavior in effort investment and learning output. Verifying this fact offers educators new ways to understand student learning behavior and assist them in improving their learning. More importantly, we also verified that the mixed pop quiz system is one of the most effective pedagogical methods for enhancing students’ learning effectiveness, which is the most important contribution of this research to higher education.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scores for exam I</td>
<td>69.75</td>
<td>12.80</td>
</tr>
<tr>
<td>Scores for exam II</td>
<td>73.04</td>
<td>16.25</td>
</tr>
<tr>
<td>Scores for exam III</td>
<td>78.03</td>
<td>13.76</td>
</tr>
<tr>
<td>Grade Point Average (GPA)</td>
<td>2.75</td>
<td>0.60</td>
</tr>
<tr>
<td>Work hours for pay per week</td>
<td>27.33</td>
<td>14.59</td>
</tr>
<tr>
<td>Total credits taken in whole semester</td>
<td>12.04</td>
<td>2.93</td>
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<tr>
<td>Frequency of studying for 1st exam</td>
<td>3.24</td>
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<tr>
<td>Frequency of studying for 2nd exam</td>
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<td>0.87</td>
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<tr>
<td>Frequency of studying for 3rd exam</td>
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<td>0.88</td>
</tr>
<tr>
<td>Attendance in the 1st exam period</td>
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<td>1.10</td>
</tr>
<tr>
<td>Attendance in the 2nd exam period</td>
<td>9.00</td>
<td>1.24</td>
</tr>
<tr>
<td>Attendance in the 3rd exam period</td>
<td>9.39</td>
<td>0.94</td>
</tr>
<tr>
<td>Daily rate of being late in Period 1</td>
<td>3.13%</td>
<td>2.48%</td>
</tr>
<tr>
<td>Daily rate of being late in Period 2</td>
<td>1.19%</td>
<td>0.94%</td>
</tr>
<tr>
<td>Daily rate of being late in Period 3</td>
<td>0.75%</td>
<td>0.79%</td>
</tr>
<tr>
<td>Daily rate of leaving early in Period 1</td>
<td>0.45%</td>
<td>0.72%</td>
</tr>
<tr>
<td>Daily rate of leaving early in Period 2</td>
<td>1.05%</td>
<td>1.01%</td>
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<tr>
<td>Daily rate of leaving early in Period 3</td>
<td>0.30%</td>
<td>0.63%</td>
</tr>
<tr>
<td>Dummy variable–male</td>
<td>0.57</td>
<td>0.50</td>
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<tr>
<td>Dummy variable–kids</td>
<td>0.28</td>
<td>0.45</td>
</tr>
<tr>
<td>Dummy variable–college algebra</td>
<td>0.73</td>
<td>0.45</td>
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<tr>
<td>Dummy variable–calculus</td>
<td>0.33</td>
<td>0.47</td>
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### TABLE 2
Comparisons of Three Systems of Unannounced (Pop) Quizzes

<table>
<thead>
<tr>
<th></th>
<th>Beginning vs. Ending</th>
<th>Mixed vs. Ending</th>
<th>Mixed vs. Beginning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explained Variable</strong></td>
<td><strong>ATD</strong></td>
<td><strong>STD</strong></td>
<td><strong>EXA</strong></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Constant</td>
<td>8.27***</td>
<td>2.64***</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>(9.89)</td>
<td>(4.27)</td>
<td>(0.46)</td>
</tr>
<tr>
<td><strong>ATD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GPA</strong></td>
<td>0.17</td>
<td>0.14</td>
<td>12.91***</td>
</tr>
<tr>
<td></td>
<td>(0.96)</td>
<td>(1.10)</td>
<td>(7.61)</td>
</tr>
<tr>
<td><strong>WHR</strong></td>
<td>0.02**</td>
<td>0.01</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td>(2.04)</td>
<td>(0.95)</td>
<td>(-0.61)</td>
</tr>
<tr>
<td><strong>CRD</strong></td>
<td>-0.01</td>
<td>0.02</td>
<td>4.98**</td>
</tr>
<tr>
<td></td>
<td>(-0.28)</td>
<td>(0.57)</td>
<td>(2.45)</td>
</tr>
<tr>
<td><strong>MAL</strong></td>
<td>0.03</td>
<td>-0.29**</td>
<td>4.98**</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(-1.90)</td>
<td>(2.45)</td>
</tr>
<tr>
<td><strong>KID</strong></td>
<td>-0.07</td>
<td>0.10</td>
<td>-3.37</td>
</tr>
<tr>
<td></td>
<td>(-0.25)</td>
<td>(0.53)</td>
<td>(-1.41)</td>
</tr>
<tr>
<td><strong>ALG</strong></td>
<td>-1.53</td>
<td>-0.92</td>
<td>-1.35</td>
</tr>
<tr>
<td><strong>CAL</strong></td>
<td>2.92</td>
<td>4.89***</td>
<td>4.11*</td>
</tr>
<tr>
<td><strong>POPb</strong></td>
<td>-0.03</td>
<td>0.48***</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>(-0.15)</td>
<td>(3.20)</td>
<td>(1.10)</td>
</tr>
<tr>
<td><strong>POPm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>4.4%</td>
<td>11.7%</td>
<td>45.8%</td>
</tr>
<tr>
<td><strong>F-value</strong></td>
<td>0.0%</td>
<td>7.5%</td>
<td>41.8%</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>134</td>
<td>134</td>
<td>134</td>
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</tbody>
</table>

Note: Number in parentheses is t-value; EXA = exam score; ATD = attendance; STD = out-of-class effort; Beginning = Pop-quiz held at the beginning of the class in Period 2; Ending = Pop-quiz held at the end of the class in Period 1; Mixed = mixed pop-quiz held at the end or/and beginning of the class in Period 3; GPA = grade point average; WHR = working hours per week; MAL = dummy variable (male student = 1); KID = dummy variable (living with kids =
1); \(ALG\) = dummy variable (algebra = 1); \(CAL\) = dummy variable (calculus = 1); \(POP_B\) = dummy variable (pop-quiz held at the beginning of the class in Period 2 = 1); and \(POP_M\) = dummy variable (mixed pop-quiz held at the end or beginning of the class in Period 3 = 1).

***\(p < .01\); **\(p < .05\); *\(p < .10\)

### TABLE 3

One-Tailed Hypothesis Test for Daily Rates of Being Late and Leaving Early (\(n = 10\))

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mixed</th>
<th>Beginning</th>
<th>Ending</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(LAT)</td>
<td>0.75%</td>
<td>0.79%</td>
<td>1.19%</td>
<td>0.94%</td>
</tr>
<tr>
<td></td>
<td>0.75%</td>
<td>0.79%</td>
<td></td>
<td>3.13%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.19%</td>
<td>0.94%</td>
</tr>
<tr>
<td>(EAR)</td>
<td>0.30%</td>
<td>0.63%</td>
<td>1.05%</td>
<td>1.01%</td>
</tr>
<tr>
<td></td>
<td>0.30%</td>
<td>0.63%</td>
<td></td>
<td>1.05%</td>
</tr>
</tbody>
</table>

***Denotes statistical significance of the \(p\)-value at the .01 level; **at the 0.05 level; and *at the 0.1 level.

Note: \(M\) = mean; \(SD\) = standard deviation; Beginning = Pop-quiz held at the beginning of the class in Period 2; Ending = Pop-quiz held at the end of the class in Period 1; Mixed = mixed pop-quiz held at the end or/and beginning of the class in Period 3; \(LAT\) = daily rate of being late; \(EAR\) = daily rate of leaving early; and \(n\) = total observations (each period included 10 classes, so \(n = 10\)).

### References


