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Group Quizzes as a Collaborative Learning Tool in Organic Chemistry

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Abstract: In this study, group quizzes were compared with individual quizzes in Organic 1 course sections to identify if students showed improved performance on exam topics supported by group or individual quizzes. Researchers also tracked the degree of student collaboration reported on quizzes and homework assignments along with student attitudes on the quiz approach. Quiz and in-class exam scores were analyzed. Questions from the American Chemical Society Organic First Semester final exam were categorized by whether that topic had been covered on an individual quiz, a group quiz, or was not covered on a quiz, and performance on these sets of topics was analyzed. Students responded very positively to the group quizzes and the data suggest they collaborated more on homework when given group quizzes. Quiz grades and in-class exam grades did not seem to be affected by quiz type. Students in the experimental semester saw a boost in ACS final exam performance on topics associated with individual quizzes when given group quizzes for part of the semester.

Keywords: Second-Year Undergraduate, Chemical Education Research, Curriculum, Organic Chemistry, Collaborative/Cooperative Learning, Testing/Assessment, Student-Centered Learning

1. Introduction

Collaborative learning describes a wide range of educational approaches which involve joint intellectual effort by a group of students [1]. The benefits of collaborative learning are numerous and have been shown repeatedly. [2] These benefits include not only academic benefits such as improved academic performance [3, 4] and retention of information [5], but psychological benefits such as reduced anxiety [6] and improved self-efficacy [7], as well as social benefits such as interpersonal skill development [8] and a sense of community. [9]

Group quizzes are a relatively simple way to introduce collaboration to the classroom by modifying an existing activity, rather than having to introduce a new activity. [10] They have been used in a range of disciplines, from engineering [10] and applied calculus [11], to communications [12], Spanish [13], and sociology. [14] Instructors have occasionally reported the use of group quizzes in chemistry courses as part of a broader collaboration-based approach [15-17], but more research is needed on the impact of group quizzes in chemistry.

Collaborative work can be difficult to integrate into a large lecture-style classroom. The smaller the group size, the more groups there are in the class. It then becomes incredibly difficult for one instructor with a large enrollment class to simultaneously facilitate all of those groups – answering questions as they arise, keeping students on track, ensuring that group members are participating equally, etc. One study has suggested that instructor management time can be minimized by using clickers for assessment of team communication skills. [18] This is certainly one option, but may not work for every instructor. Group quizzes mitigate many of these problems. Because it is a quiz, instructors are not expected to answer many questions. When a quiz grade is tied to the result, students are incentivized to stay on track, participate, and work together to achieve the highest score possible.

Group quizzes also feature another benefit: students seem to like them. Student morale, while difficult to measure, is

incredibly important on its own and has also been tied to academic performance. [19] At present, students are already struggling with alarming rates of depression, stress, and anxiety. [20] Taking group quizzes as opposed to individual quizzes gives students a chance to engage in discussion and establish peer connections, providing an avenue to reduce stress.

In this study, group quizzes were implemented in Organic Chemistry 1 for Exam 1 and 3 topics, while individual quizzes were used for Exam 2 material. The researchers expected that group quizzes would be more fun and enjoyable for students. While the group quizzes certainly represented collaborative learning on their own, the goal was also that students would form study groups outside of class after taking the group quizzes and continue that collaboration outside of class to support learning. The hypotheses of this study were that students would both enjoy group quizzes more than individual quizzes and would exhibit increased levels of collaboration on homework related to group quiz topics, which in turn would lead to improved performance on topics that were covered on group quizzes. With that in mind, the research questions for this study were:

1. Did students exhibit improved performance on topics that were covered on group quizzes compared to topics that were covered using other approaches?
2. Did group quizzes result in increased collaboration among students?
3. How did students' attitudes towards group and individual quizzes differ?

2. Methods

Students and Demographics

This study surveyed 4 sections of first-semester organic chemistry in the Fall 2018 semester. 106 students consented to participate in our study. The sample was 64.2% female and 35.8% male, as well as 11.3% Black or African American, 82.1% white, and 6.5% unknown or other. A separate 4 sections of first-semester organic chemistry in the Spring 2018 semester were used as comparison. These sections included 109 students, of which 62.4% were female and 37.6% were male, while 16.5% were Black or African American, 69.7% were white, and 13.8% were unknown or other.

Students in the experimental group signed up for not only a lecture, but also a mandatory, supplemental help session which met once a week. When there was an exam, the exam took the place of the help session. Otherwise, the help session consisted of the instructor going over the answers to the homework and answering student questions, followed by a quiz. All lecture sections, experimental and comparison, were taught by the same professor. The experimental group students were split between two helps sessions: one led by the same professor as the lecture (55 students), and one led by a second, different professor (51 students).

Format and Data Collection

There were nine multiple-choice quizzes throughout the semester. The first three, associated with Exam 1 content, were given as group quizzes. The next three, associated with Exam 2 content, were given as individual quizzes. The last three, associated with Exam 3 content, were again given as group quizzes. The quiz number and format, associated chapter in the textbook, and associated exam are summarized in Table 1. On each group quiz, students were asked to form groups of 3-5 to discuss the quiz questions and identify potential answers. Each help session containing a quiz was observed for student behavior and interactions surrounding the quiz.

Students were asked several survey questions throughout the semester. At the end of each quiz, group or individual, students were asked "About how much of the homework related to this quiz did you work on together with others from your class/group/etc.?" At the end of each exam associated with group quizzes (Exams 1 and 3), students were asked to give Likert scale responses to the statements "The group quizzes in the help sessions helped me prepare for this exam," and "The group quizzes improved my confidence for this exam." Similarly, on the exam associated with individual quizzes (Exam 2), students were asked to give Likert scale responses to the statements "The individual quizzes in the help sessions helped me prepare for this exam," and "The individual quizzes in the help sessions improved my confidence for this exam." At the end of the semester, a survey of student attitudes and perceptions towards the group quizzes was administered and a consent form was given. Survey answers were collected on Scantron forms. In the case of questions asked at the end of quizzes and exams, the questions were simply added to the existing answer sheet.

Table 1. *Semester Organization.*

Quiz Number	Chapter Topic	Quiz Type	Exam Number
1	Structure and Bonding	Group	1
2	Polar Covalent Bonds; Acids and Bases	Group	1
3	Alkanes and their Stereochemistry	Group	1
-	Mass Spectrometry and Infrared Spectroscopy	No quiz	1
4	Cycloalkanes and their Stereochemistry	Individual	2
5	Stereochemistry at Tetrahedral Centers	Individual	2
6	Overview of Organic Reactions	Individual	2
-	Alkenes: Structure and Reactivity	No quiz	2
7	Nuclear Magnetic Resonance Spectroscopy	Group	3
8	Alkenes: Reactions and Synthesis	Group	3
9	Alkynes: Introduction to Organic Synthesis	Group	3
-	Organohalides	No quiz	3
-	Reactions of Alkyl Halides: Nucleophilic Substitutions and Eliminations	No quiz	Only on final

Analysis

Scantrons were scanned to produce.dat files, which were then converted to Excel files, student comments from the end-of-semester survey were transcribed, and student demographic information was obtained from ITS. Statistical analyses were carried out in IBM SPSS Statistics 25.

3. Findings

Research Question 1: Did students exhibit improved performance on topics that were covered on group quizzes compared to topics that were covered using other approaches?

All students in the experimental and comparison semesters took the 2010 ACS first-semester Organic Chemistry standardized exam. Questions on the exam were categorized by the way the corresponding chapter was covered in the experimental semester: on a group quiz (24 questions), an individual quiz (13 questions), or by no quiz at all (12 questions) (Table 1). Questions that did not correspond well to a single chapter were not considered. The percentage of questions answered correctly was calculated for each category. It is important to remember that these corresponding quiz types are derived solely from the way the material was covered in the experimental semester and essentially represent groups of topics. In the comparison semester, no quizzes were given over any chapters or topics.

A mixed-design ANOVA was performed using this percentage as the dependent variable, corresponding quiz type as a within-subjects independent variable, and group (experimental or comparison) as a between-subjects independent variable.

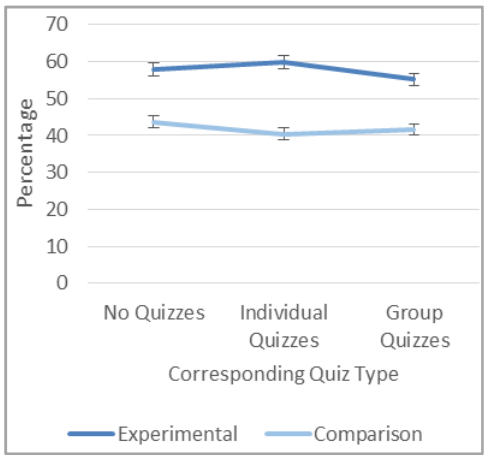

Figure 1. *Interaction graph showing percentage correct on ACS Final Exam questions corresponding to different quiz types by group (experimental or comparison). Error bars represent standard error.*

Mauchly's test of sphericity was failed (p = .008, ε = .971), so a Huynh-Feldt correction was used. A significant interaction effect was found between corresponding quiz type and group (p = .007, partial η^2 = .023). To break down this interaction, contrasts compared each level of corresponding quiz type to those questions covered by group quizzes. These contrasts revealed significant interactions when comparing experimental and comparison scores on questions corresponding to group quizzes vs. individual quizzes (p = .003, partial η^2 = .039), but not on questions corresponding to group quizzes vs. no quizzes (p = .680). The interaction graph shows that students' performance on questions corresponding to individual quizzes was enhanced in the experimental semester (Figure 1).

Convention dictates that main effects not be reported when significant interaction effects are found because they can be misleading. However, it is worth addressing the main effect of group in this case so that it is not allowed to overshadow the true result. There is a large disparity between the experimental and comparison scores. This gap represents not just differences in experimental vs. comparison, but also in semester and instructional differences. It is not surprising to see a large difference between these scores, because there were many differences between the two groups, including that experimental was on-sequence (Fall semester) and that comparison was off-sequence (Spring semester). The interesting result of this analysis is that students were most successful on the topics associated with individual quizzes in the experimental semester, despite being least successful on those topics in the comparison semester.

Within the experimental semester, quiz scores were compared. The first three and last three quizzes were group quizzes, while the middle three quizzes were individual quizzes. Chapters with "no quiz" occurred at exam weeks. A repeated measures ANOVA was performed using quiz score as the dependent variable and quiz number as the within-subjects independent variable. Mauchly's test of sphericity was failed (p <.001, ε = .658), so a Greenhouse-Geisser correction was used. While Bonferroni *post hoc* tests revealed numerous significant differences between pairs of quizzes, there was no clear pattern of group quizzes or individual quizzes resulting in higher or lower scores. The average quiz scores for the experimental semester are given in Figure 2. No quizzes were implemented in the comparison semester.

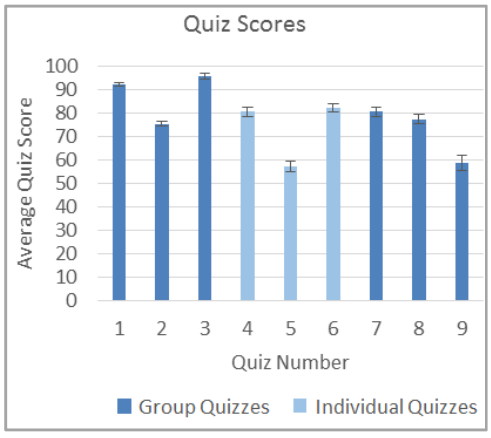

Figure 2. *Quiz scores across the experimental semester. Error bars represent standard error.*

Finally, within the experimental semester, in-class exam

scores were compared. Each exam covered four chapters, three of which were quizzed and one which was not. The quizzes for Exams 1 and 3 were group, while the quizzes for Exam 2 were individual. Average exam scores are shown in Figure 3. A repeated measures ANOVA was performed using exam score as the dependent variable and exam number as the within-subjects independent variable. Mauchly's test of sphericity was failed (p = .001, ε = .908), so a Huynh-Feldt correction was used. Exam number was found to be significant (p <.001). Bonferroni *post hoc* tests revealed that scores on Exam 3 were significantly lower than scores on Exam 1 and 2 (both p <.001), while scores on Exam 1 and 2 were not statistically significantly different from one another (p = 1.000). Exam 3 scores being lower are not necessarily surprising, as the instructor felt that the Exam 3 material was the most difficult. With the Exam 1 and 2 scores being so statistically similar, despite Exam 3 scores being lower, there was once again no clear pattern of group quizzes or individual quizzes resulting in higher or lower scores.

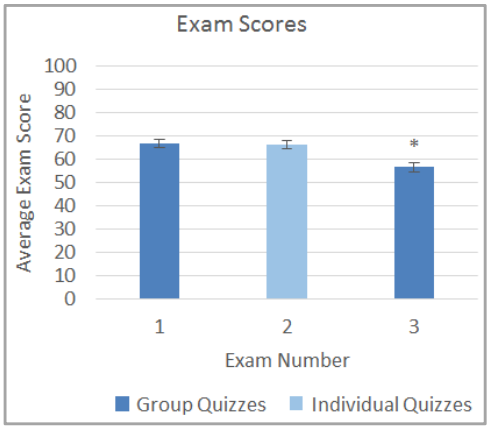

Figure 3. *Exam scores across the experimental semester. Error bars represent standard error. Asterisk denotes significant difference.*

Research Question 2: Did group quizzes result in increased collaboration among students?

Throughout the semester, students were encouraged not only to work together on the group quizzes, but to form study groups and work together on homework assignments as well. To measure whether the group quizzes were encouraging students to collaborate more outside of the classroom, at the end of each quiz, students were asked "About how much of the homework related to this quiz did you work on together with others from your class/group/etc.?" The answer choices were coded from 1 to 5, where 1 = "None of it", 2 = "Not much of it", 3 = "Around half of it", 4 = "Most of it", and 5 = "All of it".

A repeated measures ANOVA was performed using the coded response as the dependent variable and quiz number as the within-subjects independent variable. Mauchly's test of sphericity was failed (p <.001, ε = .629), so a Greenhouse-Geisser correction was used. Quiz number was found to be significant (p = .014, partial η^2 = .054). Bonferroni *post hoc* tests revealed that Quiz 9, a group quiz, was significantly different from Quiz 5 (p = .016) and Quiz 6 (p = .019), both individual quizzes. No other significant differences were found. Average coded responses are given in Figure 4.

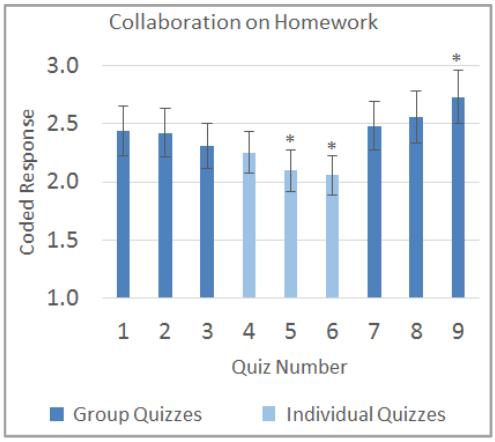

Figure 4. *Average coded responses by quiz number to "About how much of the homework related to this quiz did you work on together with others from your class/group/etc.?". 1 = None of it, 2 = Not much of it, 3 = Around half of it, 4 = Most of it, 5 = All of it. Error bars represent standard error. Asterisks denote significant difference.*

While actual significant differences were limited to those between Quiz 9 and Quizzes 5 and 6, there is a downward trend in the amount of collaboration from the first three group quizzes to the three individual quizzes, and then a marked increase in collaboration when group quizzes were reintroduced. This suggests that group quizzes did encourage collaboration outside of class.

In addition to the survey question on the quizzes, several questions regarding collaboration were asked on the End-of-Semester survey. Students were given statements and asked to rate their level of agreement on a 5-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree. Average responses are given in Table 2. The mean response for the last question (working together helped me understand material) reflects that the students found value in the group quiz discussions.

Table 2. *End-of-Semester Survey Responses on Collaboration.*

Statement	Mean Response[a]	Standard Error
Group quizzes helped me find other people to study with.	3.51	0.13
My group members all worked together to find the answers for a group quiz.	3.87	0.12
Every group member equally contributed during a group quiz.	3.29	0.13
During a group quiz, working on the problems with other people helped me better understand the material.	3.95	0.10

[a]Responses measured on a Likert scale from 1=Strongly Disagree to 5=Strongly Agree.

Finally, group quizzes were observed for student behavior. Participation was thought to be fairly good, with most

students forming groups without need for further prompting. Many groups were seen to engage in active discussion week after week, gesturing, demonstrating things on paper, and actively debating answers. Around half of the groups seemed to do work separately, then compare answers, but this still led to discussion if the group members disagreed.

Group quizzes were observed to take noticeably longer than individual quizzes. During an individual quiz, it was not uncommon for the first students to have finished the quiz by the time the last students had received the quiz paper. However, this speed was never observed during a group quiz. Instead, it was common for students to take the full amount of time given to spend time discussing their answers. This is encouraging, because it suggests that group quizzes caused students to engage with the material for longer.

In the excitement of being able to discuss answers during a quiz, some students seemed to have trouble with the rules that did apply to the quizzes, believing that the quizzes were also open-book, open-note, or that they were allowed to use their phones. The instructors and researchers do not believe that students were intentionally breaking quiz rules, but that when students heard "group quiz," they often thought it meant "anything goes." In a large lecture format, this did require someone to always circulate throughout the classroom during a quiz, keeping watch for these behaviors. Towards the end of the semester, the instructors took to reiterating the rules before each group quiz. While simple, this reminder did result in noticeably fewer incidents of undesirable group quiz behavior. After being introduced to group quizzes, some students also seemed to have trouble with the rules that applied during the switch back to individual quizzes in the middle of the semester. Cases of students verbally sharing answers during an individual quiz were much higher after having group quizzes than the instructors or researchers believed would be the case under normal circumstances. Thankfully, these issues did not persist into either the in-class exams or the ACS final.

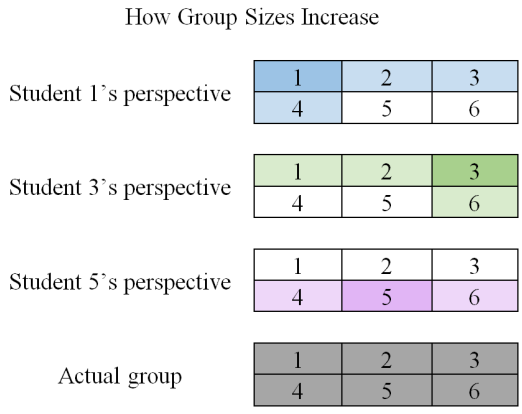

Figure 5. *Students often don't know who is in their group. For example, Student 1 (blue) may think they are working with their row and the person in front of them (light blue). Student 3 (green) may similarly think they are working with their row and the person in front of them (light green). Student 5 (purple) may think they are working with just their row (light purple). Overall, answers are being exchanged among six students (grey), even though no student thought they had a group of more than four.*

At the beginning of the study, instructors expressed a desire to keep group sizes small. Students were tasked to form groups of 3-5, but it was observed that the groups actually working together and sharing answers were oftentimes much larger. In many cases, this seemed to be unintentional as many students were often unsure of who was in their group (Figure 5). In other cases, students knew they needed to limit their group sizes but did not understand that they needed to work only within their own group. As one student explained, "Oh, well, we can't have groups larger than five, so, like, we're a group, and they're a group, and we're, like, collaborating." Groups with as many as 12 members interacting were observed. While this is undoubtedly not what the instructors had intended, this does show that students were collaborating, albeit more so than the researchers intended.

Research Question 3: How did students' attitudes towards group and individual quizzes differ?

At the end of each exam, students were given two statements and asked to rate their level of agreement on a 5-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree. For Exams 1 and 3, these statements referred to group quizzes. For Exam 2, these statements were changed to refer to individual quizzes but were otherwise identical. The first statement was, "The [group/individual] quizzes in the help sessions helped me prepare for this exam." A repeated measures ANOVA was performed using Likert-scale response (1-5) as the dependent variable and exam number as the independent variable. Exam number was found to be significant (p <.001, partial η^2 = .210). Bonferroni *post hoc* tests revealed that responses from Exam 1, associated with group quizzes, were significantly higher (M = 3.76, SE = 0.15) than responses from Exam 2, associated with individual quizzes (M = 2.53, SE = 0.16, p <.001). Responses from Exam 1 were also significantly higher than responses from Exam 3, also associated with group quizzes (M = 3.10, SE = 0.18, p = .007). Responses from Exam 3 were not statistically significantly higher than responses from Exam 2, although the difference was trending toward significance (p = .077).

The second statement students were given was, "The [group/individual] quizzes improved my confidence for this exam." A repeated measures ANOVA was performed using Likert-scale response (1-5) as the dependent variable and exam number as the independent variable. Exam number was found to be significant (p <.001, partial η^2 = .182). Bonferroni *post hoc* tests were performed. Responses from Exam 1 were again found to be higher (M= 3.40, SE = 0.15) than responses from Exam 2 (M = 2.32, SE = 0.15, p <.001). Responses from Exam 1 were not statistically significantly higher than responses from Exam 3 (M = 2.88, SE = 0.18), although the difference was trending toward significance (p = .056). Responses from Exam 3 were not statistically significantly higher than responses from Exam 2, although the difference was trending toward significance (p = .055).

Table 3. *End-of-Semester Survey Responses on Student Attitudes Toward Quizzes.*

Statement	Mean Response[a]	Standard Error
The topics from the chapters that there were no quizzes for were more difficult for me on the exams because I had not prepared with a quiz.	2.85	0.11
Group quizzes helped me prepare for exams more than individual quizzes.	3.68	0.13
Group quizzes improved my confidence more before exams than individual quizzes.	3.80	0.13
Group quizzes were more enjoyable than individual quizzes.	4.53	0.09
Group quizzes were more stressful than individual quizzes.	1.49	0.08
Group quizzes were easier than individual quizzes.	4.14	0.10
I prefer group quizzes to individual quizzes.	4.57	0.09

[a]Responses measured on a Likert scale from 1=Strongly Disagree to 5=Strongly Agree.

In general, students were most likely to believe that the group quizzes helped them prepare and improved their confidence on Exam 1, and least likely to feel the individual quizzes helped them prepare or improved their confidence on Exam 2.

In addition to the survey questions on the exams, several questions regarding student attitudes toward the group and individual quizzes were asked on the End-of-Semester survey. Students were given statements and asked to rate their level of agreement on a 5-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree. Average responses are given in Table 3. Students were found to rate group quizzes more positively than individual quizzes on every statement given.

4. Limitations

This study originally intended to incorporate a much larger sample of students in the Fall 2018 semester, as well as an entire additional semester in Spring 2019. Unfortunately, after the first four sections of students in Fall 2018 took the ACS standardized final, the exam was found to be compromised and the rest of the students took a different version of the ACS standardized final. Due to the compromise, a third version of the ACS final was ordered and implemented by the department in Spring 2019. In order to keep the sample as directly comparable as possible, the analyses as straightforward as possible, and to avoid any possible data skew from the compromise, the decision was made to pare the sample back to only those students who took the 2010 ACS standardized final, pre-exam compromise. Data from the larger sample was encouraging in supporting the group quiz implementation, however, due to the circumstances, these researchers feel it would be inappropriate to report and suggest that further research with a larger sample is needed.

Of course, due to the pared down sample, the analyses in this study focus on an on-sequence experimental group and an off-sequence comparison group, among other differences between semesters. This contributes to the large main effect difference between groups in Figure 1, but because the focus of that analysis is the interaction effect, these group differences should not be reflected in the findings reported.

Finally, although all lectures for the sample and comparison sections were taught by the same professor, the help sessions were taught by two different professors. It is possible that instructor differences in the help sessions alone could have impacted these results. However, efforts were made to minimize these differences by keeping the help sessions consistent. The instructors used identical materials and followed the same help session format.

5. Discussion

Overall, it seems that students in the experimental group performed similarly on topics associated with group quizzes and no quizzes on the ACS standardized final but exhibited improved performance on test topics that were covered on individual quizzes. This is directly opposed to the survey results, in which students were less likely to believe that the individual quizzes helped them prepare for the exam or improved their confidence compared to the group quizzes. It may be that taking a quiz alone after getting used to group quizzes increased the pressure on students in the experimental group and caused them to study more thoroughly for individual quizzes. However, this is purely speculation and needs further study to really explain.

These findings do suggest that students were collaborating on group quizzes and possibly collaborating more outside of the classroom in weeks of group quizzes compared to individual quizzes. Notably, students felt that working with other people on the group quiz helped them to better understand the material (Table 2).

While group quizzes did not seem to directly affect quiz or in-class exam scores one way or the other, they proved to be very popular with students, who credited them with being better for in-class exam preparation, improving confidence before exams, more enjoyable, less stressful, easier, and just generally preferred. In addition, there was no clear pattern of group quiz grades being higher or lower than individual quiz grades (Figure 2), eliminating potential instructor concern about skewing the quiz grades too high during group work.

6. Implications

Group quizzes were found to be strongly preferred by students in every capacity when compared to individual quizzes but did not seem to affect quiz or in-class exam scores. The original study design included an additional semester that would have enabled further comparison, such as a more detailed analysis of how group and individual

quizzes differed in their effect on quiz and in-class exam scores. Unfortunately, due to the final exam compromise and subsequent loss of that semester worth of data for comparison, further study is needed to distinguish between the levels of support offered to students by group and individual quizzes. In the experimental group described here, there was no clear pattern of group quizzes resulting in either higher or lower quiz scores and/or in-class exam scores. Group quizzes did not skew the grades in any measurable way. By that very merit alone, instructors are encouraged to use them as a way to improve student morale without affecting these scores.

Longer-term, on the ACS standardized final, students in the experimental group performed best on topics covered by individual quizzes, while students in the comparison group performed worst on that same set of topics and questions. This suggests that something about the quiz implementation may have bolstered student performance on individual quiz topics. For instance, students may have studied harder for the individual quizzes when not all quizzes were individual quizzes. The exact cause of this effect will require additional study. In the meantime, instructors might consider using a mix of group and individual quizzes selectively to improve overall student morale and boost collaboration on specific topics.

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