



# **The Effects of Assessment Method for Regular, Out-of-Class, Learning on Student Performance and Content Retention in a System Dynamics Course**

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## **Introduction**

Over two decades ago, Feldmann asked instructors to look carefully at the desired outcome of homework and ask why they do what they do [1]. This work seeks to answer this question by critically looking at formative assessment, such as homework and quizzes, and how to encourage students to reap the most benefit. It is generally well known that students completing regular formative assignments, such as homework, helps them to understand the material and perform better on exams [2]-[5]. Unfortunately, this is dependent on students taking these assignments seriously and doing the work. Several studies [4], [6], [7] have shown that if students do not put forth effort on these assignments, they do not achieve the benefits, and little more is accomplished than frustration from both students and faculty alike. Therefore, for several years now, researchers have been searching for ways to better incentivize students to give these formative assignments the effort they are due while decreasing the time burden on faculty, or at least not increasing it.

Several studies have investigated how, and even if, homework is graded and the findings are generally that there is no statistically significant difference between these different grading modalities for homework [6], [8], [9]. The biggest impact seems to be getting students to do the work [4], [8], [9]. For example, Lura et al. [10] and Fernandez et al. [11] found that there was no statistically significant correlation between graded homework and exam performance. However, there was significant correlation between quiz and exam performance. This likely indicates that extrinsic motivation is necessary for students to take such formative assignments seriously, indicating that methods to encourage students to take such work seriously are required. There have been some studies that report minimal improvements in course or exam grades with quizzes [12]-[16], but most of these are a combination of small differences, small number of students, or lack of statistics to determine if changes were significant. Therefore, quantitatively, there does not appear to be a strong argument for one method over the other.

Much of the literature indicates that getting the students to do the formative work is most important. Therefore, the following three factors are forefront in determining the best method to use:

- 1) Minimize students copying solutions from manuals or each other. That said, students taking time with the material is most important, so there has been some success with instructors providing solutions, especially if accompanied by explanations from the instructors [17], or students self-grading homework [18].
- 2) Reduce instructor work load. If there is no clear best for the students, then it is reasonable to use formative assignments that reduce the workload on the instructor. Generally, it is a lower grading burden to grade a ten minute in-class quiz than a homework set, and with most studies showing no change, or improvement in student performance [12]-[16] replacing homework with quizzes is warranted.

- 3) Student impression seems to generally view graded quizzes instead of homework favorably, with some studies indicating that constantly preparing for quizzes helps students stay up to date on the course work [19], [20].

Haddad and Kalaani [18] sought to address the first two factors by having students self-grade homework and found some success; though, this does add to the time burden of students, so care would be needed in implementing this approach. Reisel [21] addressed all three factors by investigating how grading homework versus giving quizzes affected student performance in a thermodynamics course. The implementation was very similar to the original implementation for the work presented herein where homework was suggested and in-class quizzes were graded. Reisel found that student grades did increase under this modality. One difference in this study from the current one was that students were allowed to use the work they did on homework when taking quizzes. The work presented within also expands on this study by investigating an iteration where both homework and quizzes were included in the students' grades.

The present study contributes to this robust body of literature by looking at three different formative assessment modalities: homework only, quiz only, and hybrid, where homework was graded for completion and quizzes were taken the class period after homework was submitted. This last modality was not very prevalent in the literature, but is admittedly a minor variation on many of the works presented. This work seeks to further expand the robust literature available by looking at grades in a follow-on class, and taking care with the data to factor by performance in previous courses to see if the interventions have different effects on different groups of students.

## **Methods**

Three assessment modalities were tested as follows:

Homework only (H): Students completed weekly homework assignments consisting of problems related to topics covered in class that week. These assignments were collected and a subset of the problems were graded for correctness. Homework solutions were provided after homework was collected.

Quiz only (Q): Students were encouraged to complete weekly homework assignments similar to those given for assessment H. Homework was not collected, and students were also given solutions at the time the assignments were assigned. Students then completed an in-class quiz the day the homework assignment was "due," consisting of one problem very similar to one of the homework problems.

Quiz and homework (QH): Students completed weekly homework assignments similar to those given in the other two modalities. The assignments were collected and graded for completion only, not for correctness. The day that the homework was due, students were given solutions. The following class period, students completed an in-class quiz similar to the quizzes given for assessment Q.

**Table 1:** Assessment modality, instructors, and number of students for each course offering.

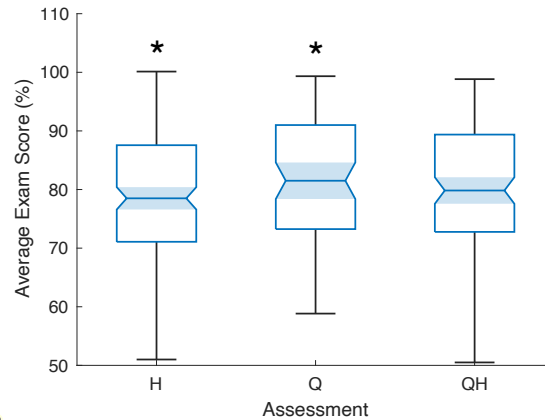
Offering	2014	2015	2016	2017	2018	2019	2020	2021
Assessment	H	H	H	H	Q	Q	QH	QH
# Students	39	54	41	50	39	41	70	63
Instructor(s)	A	A & B	A & B	A & C	A & C	A	A	A

For all three assessment types, two in-class midterm exams and one cumulative final exam were given. The three assessment modalities were given at different times over the past eight years in a system dynamics course to the entire cohort of junior mechanical engineering students at Ohio Northern University, a small, private, midwestern institution (Table 1). The course is offered every Fall semester, and at least one section of each course offering was instructed by the primary author, ensuring that the course structure, homework, quiz (when applicable), and exam content were comparable across years. Fall 2014 through Fall 2017 consisted of assessment H (184 students), while Fall 2018 and Fall 2019 had assessment Q (80 students), and finally Fall 2020 and 2021 had assessment QH (133 students).

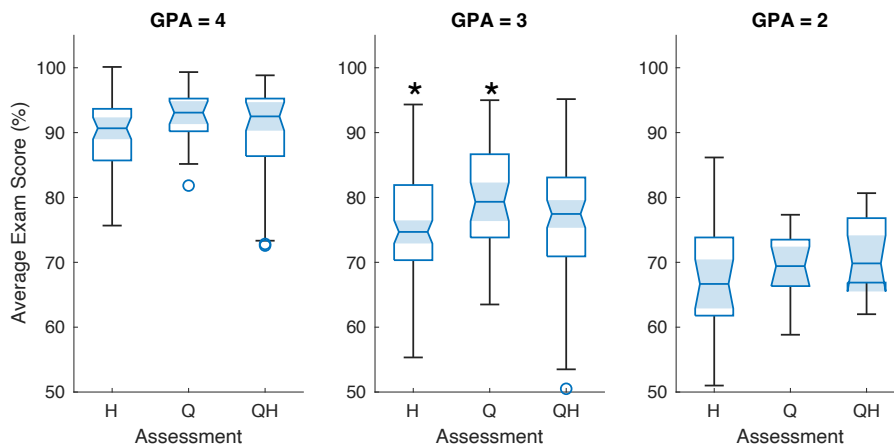
In order to test the effects of homework assessment in the given course, students' average exam score, cumulative GPA when entering the course, and final course grade in the follow-on system dynamics course were collected. Incoming GPA was included to factor out different calibers of students based on their performance in previous coursework at the institution. The final course grade in the follow-on course was included to test the effects of assessment type on content retention. A majority of the students from Fall 2014, and a handful of other students did not have follow-on course grades, as these students took a similar course in a different engineering department. Similarly, students in Fall 2021 are currently taking the follow-on course, so they were excluded from this analysis as well. The remaining students all took the follow-on courses with instructors B or C. Before obtaining data, this study was approved by the University's Institutional Review Board.

Evaluation of assessment type on student performance was performed with a two-way ANOVA ( $\alpha = 0.05$ ), testing average exam score against the factors of assessment modality (H, Q, QH) and incoming GPA (rounded to the nearest integer to maintain larger group sizes). Evaluation of assessment type on content retention was performed with a two-way ANOVA ( $\alpha = 0.05$ ), testing course grade in the follow-on course against the same factors. For both analyses, post-hoc testing was performed via multiple comparisons tests.

Finally, in order to rule out the possibility that the students in a particular assessment type might generally be of a higher caliber, students' GPA was tested against assessment type. This was performed with a one-way ANOVA ( $\alpha = 0.05$ ), testing students' incoming GPA (not rounded as before) against the factor of assessment modality. Should GPA not be significantly different between assessment modalities, there can be higher confidence that the results above are truly due to the differences in assessment.



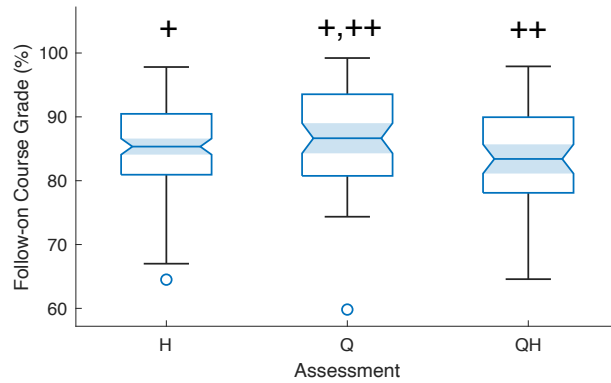
**Figure 1:** Box plots of average exam score versus assessment modality for all GPA. \* indicates significantly different pairs ( $\alpha = 0.05$ ).



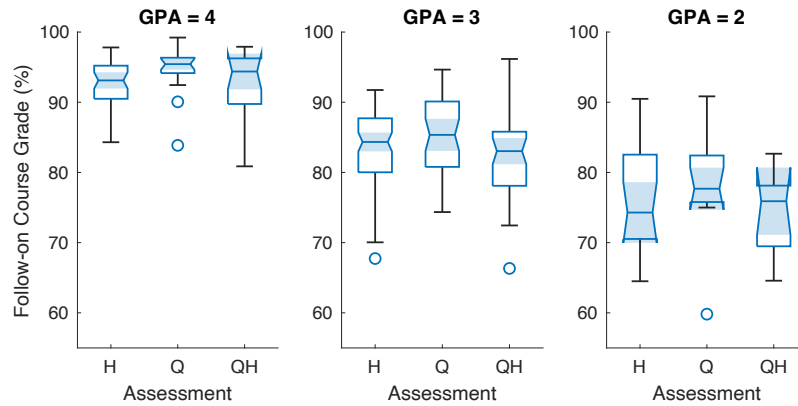
**Figure 2:** Box plots of average exam score versus assessment modality, separated by rounded incoming GPA. \* indicates significantly different pairs within GPA ( $\alpha = 0.05$ ).

## Results

The two-way ANOVA for average test score indicated that both assessment ( $p = 0.0091$ ) and GPA ( $p < 0.0001$ ) significantly affected student performance within the course, but their interaction was not significant ( $p = 0.6470$ ). Following up with a multiple comparisons test for assessment (not accounting for difference in GPA), average test score for assessment Q was significantly higher than for assessment H (Fig. 1). The multiple comparisons test considering both factors indicated that within each GPA group, assessment Q was significantly higher than H for rounded GPA of 3. No other significant differences were found within GPA of 4 or GPA of 2 (Fig. 2). Significant differences in student performance distinguished by GPA alone are rather obvious and will not be presented or discussed.



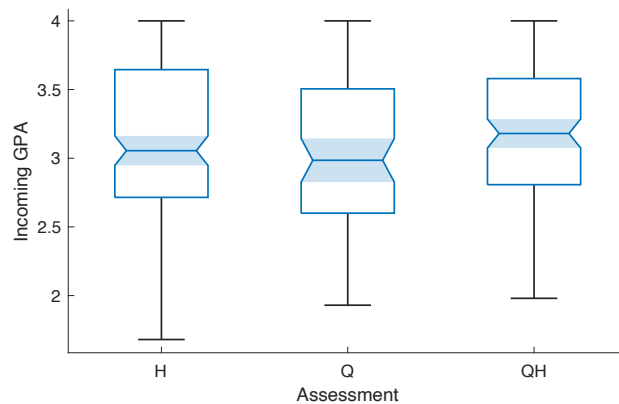
**Figure 3:** Box plots of follow-on course grade versus assessment modality for all GPA. +, ++ indicate significantly different pairs ( $\alpha = 0.05$ ).



**Figure 4:** Box plots of follow-on course grade versus assessment modality separated by rounded incoming GPA. +, ++ indicate significantly different pairs ( $\alpha = 0.05$ ).

The two-way ANOVA for follow-on course grade similarly indicated that both assessment ( $p = 0.0103$ ) and GPA ( $p < 0.0001$ ) significantly affected student content retention, but their interaction was not significant ( $p = 0.9188$ ). Following up with a multiple comparisons test for assessment (not accounting for difference in GPA), follow-on course grade for assessment Q was significantly higher than both other assessments (Fig. 3). The multiple comparisons test considering both factors indicated that student content retention was not significantly affected by assessment modality within GPA groups (Fig. 4).

The one-way ANOVA for incoming GPA indicated that it was not significantly different between assessment modalities ( $p = 0.1272$ , Fig. 5).



**Figure 5:** Box plots of incoming GPA versus assessment modality.

## Discussion

The results presented above suggest that there may be some benefit to assessing out-of-class homework through in-class quizzes rather than simply grading the homework assignments. Considering all students, regardless of their cumulative GPA when entering the course, the quiz assessment modality led to statistically-significant higher average exam scores versus the homework assessment modality (Fig. 1). While the difference between QH and H assessments was not significant, exam performance was slightly higher for QH. Therefore, looking broadly at course performance as a whole, it seems that students benefit from a weekly quiz covering suggested homework material rather than weekly graded homework. However, they may not benefit as much, or at all, when the quiz is combined with collected homework.

When grouping students by GPA, the same general trend ( $Q > QH > H$ ) held for GPAs rounded to four and three (Fig. 2). Students with a rounded GPA of three even showed statistically-significant higher exam scores for Q versus H. However, when looking at students with a rounded GPA of two, while not statistically significant, their average exam scores were highest for QH, then Q, then H. These results suggest that perhaps for top students, assessment modality may not matter, but average students benefit from the added accountability of trying to understand the homework in order to do well on the quiz, rather than copying the answers for a higher homework grade. Also, for lower-caliber students, it seems that the hybrid modality of completing the homework and studying for the quiz provides the most benefit, but again, this trend was not statistically significant.

The same general trends are apparent when looking at content retention as well. Considering all students, regardless of GPA, assessment modality Q led to statistically significant higher follow-on course grades than both H and QH. Interestingly, students with assessment H performed slightly better than QH in the follow-on course, but this difference was not statistically significant. When grouping students by GPA, assessment Q was higher than the other two, but the difference was never statistically significant. These results suggest that benefits of a weekly quiz after suggested, but not collected, homework improved content retention after the course in question, but perhaps not to the same level. It should be recalled that assessment QH only has one offering of data, which may skew the results here.

A natural question arises as to whether students who took the course during assessment Q were perhaps higher caliber than either the H or QH assessment modalities. Testing GPA (not rounded) against assessment type proved that there were no statistically significant differences between the modalities (Fig. 5). In fact, the trends show that students in the Q assessment modality had a slightly lower average GPA than the other two modalities. This further enforces the findings above that suggested homework followed by a quiz provided students the most benefits to in-class performance and content retention.

## Conclusion

This study presented data on in-class performance and content retention for three different formative assessment modalities in a system dynamics course taught to mechanical engineering juniors. While there were no staggering differences between the three modalities, the results tend to agree with the varying results in the literature. In this case, providing weekly suggested homework assignments (with solutions) followed by a quiz proved to be the best mode of assessment to improve students' performance in the course, as well as content retention for a follow-on course. A question arises as to why this modality was more successful than weekly collected homework (for completion grade only) followed by a quiz, which is an area for future work where more data points can be obtained.

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