10-2020

Correlation of Student Participation in Practice Exams and Actual Exam Performance

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Paper ID #32143

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Abstract

Background: Practice exams are a type of formative feedback. These can be administered through learning management systems such as D2L and Canvas as low stakes assessment. This paper intends to show the relationship between students' participation in online practice exams and their scores on the actual exams.

Research Questions: Does participation in timed, online practice exams correlate with improved actual exam performance on similar questions? Does a correct answer in a timed, online practice exam correlate with obtaining the correct answer on the actual exam on a similar question? Does participation in timed, online practice exams correlate with improved overall course grades?

Design/Method: The context of data collection includes mechanical engineering courses taught by the same instructor across thermodynamics, heat transfer, and dynamics. The practice exam questions and actual exam questions were designed from textbook homework questions, but with different surface characteristics. One question on the actual exam closely matched the single practice exam question provided. The students received an instant score from D2L or Canvas. This correlational study reviewed the factors of participation and score on practice exam, on the outcomes of score on actual exam and overall course grades.

Results: Participation in practice exams correlates well with improved exam scores and improved overall course grades by about 1 letter grade for younger students. The score on the practice exam does not correlate with actual exam performance.

Conclusions: Formative feedback is beneficial to younger students. There are many types of formative feedback. Engineering educators should adopt an appropriate form of formative feedback for younger students in exams.

Keywords: formative assessment, feedback, mechanical engineering science, online virtual learning

Background

There seems to be a persistent discrepancy between performance on homework problem solving and exams in lower level engineering science courses, but instructors often hope that homework is an accurate predictor of the exam outcomes. Common themes on end-of-semester course evaluations from students often include a complaint that they were not adequately prepared for the exams and that homework was not returned soon enough or graded carefully enough to be useful exam study material. Additionally, instructors may purposefully design exam questions that are more difficult than any of the assigned homework questions. Readily available solution manuals and homework help websites further confound the issue. Assuming that engineering students will make an honest attempt to learn the material if they believe that they can succeed in the course, what can instructors do besides textbook homework to support student learning before the exam?

Since 1999, engineering educators have been publishing conference papers on their efforts to design online homework and practice exams. At first, there were homegrown codes and websites (K. Davis; K. A. Davis; Estell; Gehringer; Griffin, Swanson, Randolph, & Owen; Knight, Nicholls, & Componation; Mehrabian, Ali, Buchanan, & Rahrooh; Miller, Brauer, & Sharber; Ng & Gramoll). Then commercially available homework systems became popular and included analytics for faster review by faculty (Feldman, Bullock, & Callahan; Head, Owolabi, & James-Okeke; Shalabh). Engineering educators have considered the effect of time limits on exams (Ramming & Mosier; Verleger). Recently, engineering educators have used the conceptual framework of "low stakes assessment" to frame their efforts (Creasy; Dimas, Jabbari, & Billimek).

"Low stakes assessment" implies that the grade on the assessment will not largely influence the overall course grade at the end of the semester. What do any numerical grades mean to instructors and what do they mean to students? Over 100 years of summative (end of semester or end of year) grades across all levels of education show increasing sophistication in designing assessments. The ABCDF scale used in higher education implies that an instructor can assess a student's abilities into 5 unique categories, relative to other classmates, and we expect a normal distribution. But K-12 education has begun the switch to standards-based grading, where student achievement and minimum acceptable mastery of the material is defined by a rubric. Increasingly, pockets of higher education are adopting standards-based grading (Brookhart et al., 2016).

The Committee on the Foundations of Assessment and the Board on Testing and Assessment, Center for Education, National Research Council, published the latest advances in assessment as a natural extension to the book *How People Learn*. A major recommendation in *Knowing What Students Know* for policy and practice is that "the balance of mandates and resources should be shifted from an emphasis on external forms of assessment to an increased emphasis on classroom formative assessment designed to assist learning" (Pellegrino, Chudowsky, & Glaser, 2001). The practice exams that are the focus of this paper are essentially forms of formative feedback.

Formative feedback to assist learning includes three feedback questions, essentially 1) how am I going? 2) where am I going? and 3) where to next? To assist students' learning, feedback should build cues for more effective strategies for processing material and provide cue for directions for searching and strategizing. Students also need to have time and resources to respond to feedback (Hattie, 2007).

Conceptual Framework

Shute (2008) operationalized the concept of formative feedback by arraying feedback types loosely by complexity. This provides a simple way to compare different efforts described in the engineering education literature and to understand their relative impact on students' improvement. Generally, more complex feedback may result in greater student learning, but actual learning results may vary due to many confounding factors. Additional complexity also implies but does not guarantee greater instructor workload. Shute's Table 1 is recreated here.

Table 1. Reproduction of Table 1 Feedback types arrayed loosely by complexity (Shute, 2008).

Feedback type	Description
No feedback	Refers to conditions where the learner is presented a question and is required to respond, but there is no indication as to the correctness of the learner's response
Verification	Also called "knowledge of results" or "knowledge of outcome". It informs the learners about the correctness of their responses (e.g. right-wrong, or overall percentage correct).
Correct response	Also known as "knowledge of correct response". Informs the learner of the correct answer to a specific problem, with no additional information.
Try again	Also known as "repeat-until-correct" feedback. It informs the learner about an incorrect response and allows the learner one or more attempts to answer it.
Error flagging	Also known as "location of mistakes". Error flagging highlights errors in a solution, without giving correct answer.
Elaborated	General term relating to the provision of an explanation about why a specific response was correct or not and may allow the learner to review part of the instruction. It may or may not present the correct answer (see below for six types of elaborated feedback).
Attribute isolation	Elaborated feedback that presents information addressing central attributes of the target concept or skill being studied.
Topic contingent	Elaborated feedback providing the learner with information relating to the target topic currently being studied. May entail simply reteaching material.
Response contingent	Elaborated feedback that focuses on the learner's specific response. It may describe why the incorrect answer is wrong and why the correct answer is correct. This does not use formal error analysis.
Hints/cues/prompts	Elaborated feedback guiding the learner in the right direction, e.g., strategic hint on what to do next or a worked example or demonstration. Avoids explicitly presenting the correct answer.
Bugs/misconceptions	Elaborated feedback requiring error analysis and diagnosis. It provides information about the learner's specific errors or misconceptions (e.g., what is wrong and why).
Informative tutoring	The most elaborated feedback (from Narciss & Huth, 2004), this presents verification feedback, error flagging, and strategic hints on how to proceed. The correct answer is not usually provided.

Shew, Maletsky, Clark, and McVey (2019) describe a practice exam program developed at the University of Kansas with compelling improvements in student retention in the engineering program and learning results. It includes a face-to-face session of a student first working individually on a practice exam, then working with a partner, then working with a more experienced student staff instructor. The effect was a reduction in DFW rates from average 30% to at most 3%. In Shute's framework, this program may be the most complex form of feedback, informative tutoring.

The practice exam effort described in this paper is at the low end of the spectrum, verification, where students' numerical responses are simply marked correct or incorrect.

Research Questions and Hypotheses

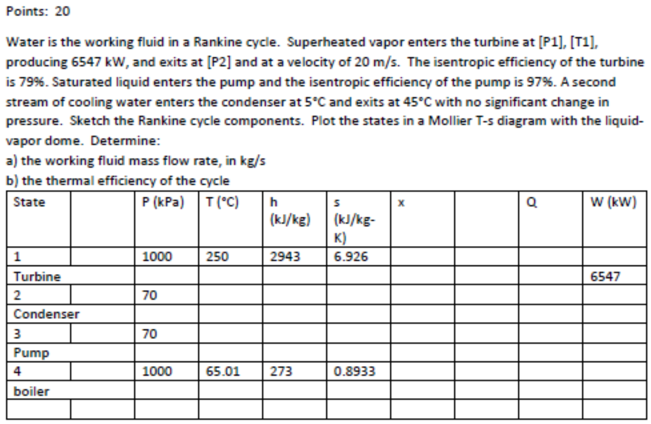
This paper addresses the following research questions:

- Does participation in timed, online practice exams correlate with improved actual exam performance on similar questions?
- Does a correct answer in a timed, online practice exam correlate with obtaining the correct answer on the actual exam on a similar question?
- Does participation in timed, online practice exams correlate with improved overall course grades?

The hypothesis is that participation in and obtaining correct answers in timed, online practice exams will both positively correlate with improved exam performance and overall course grades. Practice exams with immediate correct/incorrect feedback are a type of formative feedback, meant to support students' learning. Additionally, applying the time constraints of the actual exam to the practice exam may reduce students' fear due to the uncertainty of how the exam will be administered. The data included in this paper are sufficient to obtain answers to these research questions.

Design/Method

The design of this research study is correlational with archival data. At no time during the semesters in which timed, online practice exams were available to students did I attempt to manipulate or control the independent variables or confounding factors. Every student in a course section received the same practice exam questions, for the same amount of time, and received the same exam questions (varying only numeric quantities, while key concepts remained the same), see Figure 1, and the same time to complete the exams, for all of the exams administered in the semester. The population who had practice exams available were not compared to other sections of the same course without access to practice exams. All the practice exams in every course were administered through the university's learning management system (D2L or Canvas, see Figure 2) and were allotted 15 – 40 minutes, depending on how many questions and time allotted were anticipated on the actual exam.



Points: 20

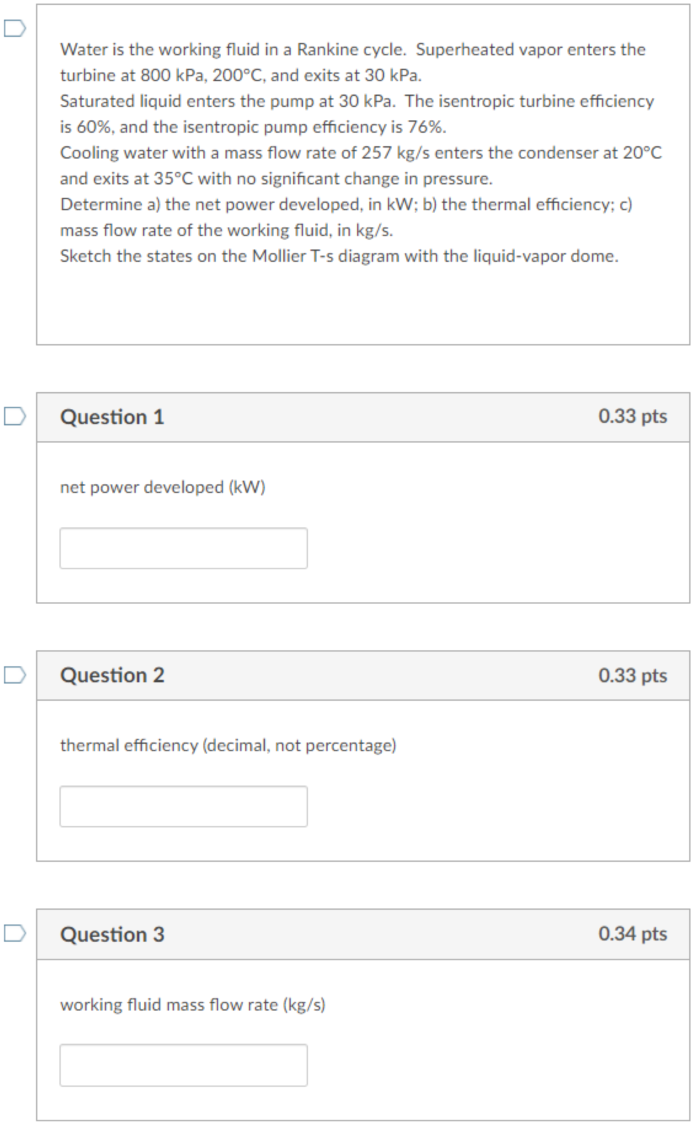
Water is the working fluid in a Rankine cycle. Superheated vapor enters the turbine at [P1], [T1], producing 6547 kW, and exits at [P2] and at a velocity of 20 m/s. The isentropic efficiency of the turbine is 79%. Saturated liquid enters the pump and the isentropic efficiency of the pump is 97%. A second stream of cooling water enters the condenser at 5°C and exits at 45°C with no significant change in pressure. Sketch the Rankine cycle components. Plot the states in a Mollier T-s diagram with the liquid-vapor dome. Determine:

a) the working fluid mass flow rate, in kg/s

b) the thermal efficiency of the cycle

State		P (kPa)	T (°C)	h (kJ/kg)	s (kJ/kg-K)	x		Q	W (kW)
1		1000	250	2943	6.926				
Turbine									6547
2		70							
Condenser									
3		70							
Pump									
4		1000	65.01	273	0.8933				
boiler									

Figure 1. Example problem statement from the thermodynamics final exam, on paper.



Water is the working fluid in a Rankine cycle. Superheated vapor enters the turbine at 800 kPa, 200°C, and exits at 30 kPa.
Saturated liquid enters the pump at 30 kPa. The isentropic turbine efficiency is 60%, and the isentropic pump efficiency is 76%.
Cooling water with a mass flow rate of 257 kg/s enters the condenser at 20°C and exits at 35°C with no significant change in pressure.
Determine a) the net power developed, in kW; b) the thermal efficiency; c) mass flow rate of the working fluid, in kg/s.
Sketch the states on the Mollier T-s diagram with the liquid-vapor dome.

Question 1 0.33 pts

net power developed (kW)

Question 2 0.33 pts

thermal efficiency (decimal, not percentage)

Question 3 0.34 pts

working fluid mass flow rate (kg/s)

Figure 2. Practice exam question administered through Canvas.

The courses included in this study were all taught by the same instructor in the mechanical engineering department but were three different subjects. In 2018 fall, sophomore level thermodynamics employed practice exams for two midterm exams and the final exam. The actual exams were conducted in class. Only the final exam and associated practice exam have sufficient data for this study. In 2019 spring, junior level heat transfer employed practice exams for three midterm exams but there was no practice exam for the final exam in this course. The actual exams were conducted in class. All three midterm exams have sufficient data for this study. Lastly, in 2020 spring, early sophomore dynamics class had practice exams for three midterm exams, but no practice for the final exam. The first exam was conducted in class, and because of the COVID-19 nationwide lockdowns, the remaining actual exams in the course were conducted online. Only the third midterm exam has sufficient data for this study.

There are two reasons that data may be insufficient. Firstly, it may be unclear that a student participated in the practice exam; a 0 grade in the archival gradebook does not necessarily imply only non-participation. Secondly, there may not be a record of which question on the actual exam mapped to the practice exam in the archival gradebook.

Standardized grading was employed in all courses considered. In the case of in-class exams, grades were recorded out of 20 points. In the case of online exams, the numerical solution was separately recorded on the gradebook for 1 point out of 20. See Table 2 for an example rubric for standardized grading. In all three courses, numerical solution is worth 1 point out of 20.

Table 2. Example of rubric for standardized grading.

Step	Explanation	Credit
KNOWN	Parameters and properties that are given in the problem statement	1
UNKNOWN	Parameters and properties that are to be determined	1
PICTURE/SKETCH	Components of the system and how they are connected	1
Boundaries	Identify the important parts of the system	1
Labels	Draw arrows with words, symbols for parameters, initial & final state	1
ANALYSIS		
ASSUMPTIONS	Simplifications (what can be ignored or equals 0) or idealizations Identify the system as *control volume* or *closed system (control mass)*	2
Governing LAWS and equations	Preferably something that includes the knowns, unknowns, and assumptions; will likely include 1st law, 2nd law, ideal gas law	3
SIGN convention	Positive/negative directions for parameters like heat transfer and work	1
PLOTS/TABLE look-ups	as needed, pressure/volume/temperature/energy/entropy plots and sketches may explain the problem and be used in the calculations	2
CALCULATIONS	Apply calculus, algebra, calculators, and/or computer codes/programs Substitute numerical values into equations	2
Properties	Species name; pressure; temperature; volume; energy; entropy	1
Values of properties	Numerical values from calculations, table look-ups, or from the problem statement	1
Units of properties	English system or SI system, per property or parameter	1
underline, or box the final SOLUTIONS	Make the answer to the unknown really obvious	1
Engineering writing	All capital letters where applicable	1

The data were coded for analysis of variance (ANOVA) using Minitab 19.2, with a 95% confidence interval. Participation, as recorded by the learning management system's record of who accessed the practice exam, was coded as 1=participated or 0=not participate. Score on the online, timed practice exams were only the numerical solutions, for a maximum score of 1. Score on actual exams for in-class exams was recorded out of 20 points from *Table 2* rubric, but without detail on whether the numerical solution was correct. Score of actual exams in spring 2020 administered online were recorded out of maximum possible 1 point for the correct numerical solution. Overall course grade in every course was recorded in the grade book out of 100% (computed from weighted percentages of homework, exams, and projects). Since every course varied from each other in some detail of available data, conclusions may be drawn only with caveats.

Results

Sophomore thermodynamics in 2018 fall, considering only participation in a practice exam, showed statistically significant improvement in the final exam score and overall course grade with participation in the practice exam question for the final (though the detail of the correctness of the solution is not recorded in the gradebook). Out of 100 students, 36 did not participate, 64 participated. There was about a 2-letter grade improvement in the 1 question in the exam for which there was practice, see Figure 3. The topic in the practice exam was Rankine cycle analysis, shown in Figure 1. There was a full letter grade improvement in the overall course grade for those who participated in practice final exam question, see Figure 3. But the score on the practice exam was not significant in performance on the actual exam or in the overall course, see Figure 4. These results influenced the instructor's willingness to continue administering practice exams in other courses in later semesters.

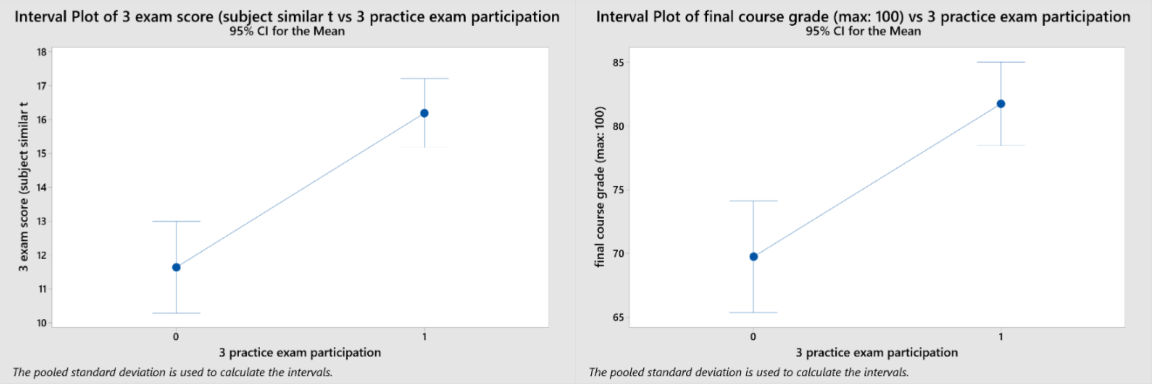


Figure 3. Thermodynamics. Comparison of participation for final exam score (left). Comparison of participation for overall course grade (right).

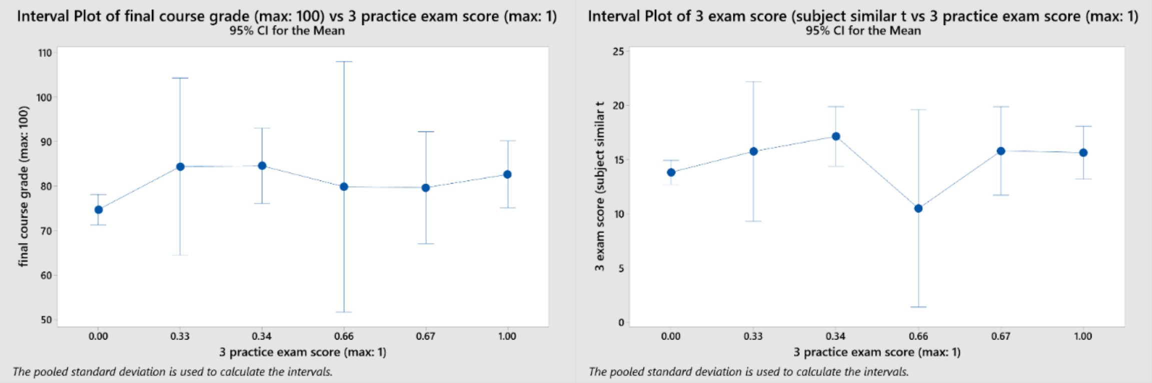


Figure 4. Thermodynamics. Comparison of score in practice exam to actual exam (left). Comparison of practice exam score and overall course grade (right).

Sophomore dynamics in 2020 spring showed no distinct trends with participation in practice exam questions, for several reasons. Firstly, this was the first time for this instructor to teach the subject, so initial instruction influences the exam scores. Secondly, the practice exam 3 question was written for a lower level of difficulty than the actual exam question, so it was insufficient practice. The subject was rigid body acceleration of a single component instead of a multi-component device. Thirdly, because of the abrupt switch in teaching mode due to COVID-19, much grace was applied to the overall course grades. The only conclusion here must be drawn regarding the teacher's proficiency with the subject and with exam writing.

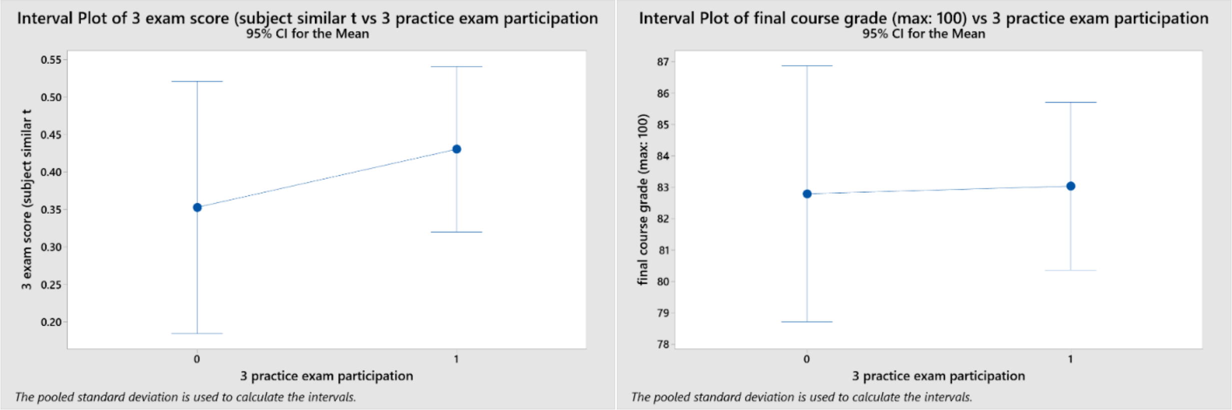


Figure 5. Dynamics. Comparison of participation in practice exam vs. actual exam score (left). Comparison of participation in practice exam 3 with overall course grade (right).

Junior level heat transfer in 2019 spring has a complete data set for all midterms and final exam. There were no statistically significant improvements in exam grades but improvement in overall course grade with participation in practice exams. Participation in midterm practice exams resulted in a tighter confidence interval, bringing up the low end of the actual exam question by a full letter grade, see Figure 6. However, consistent participation in several practice exams had a statistically significant correlation with improved overall course grade, see Figure 7. Consistent participation may indicate that these upperclassmen have more mature study habits as compared to the sophomore dynamics and thermodynamics students.

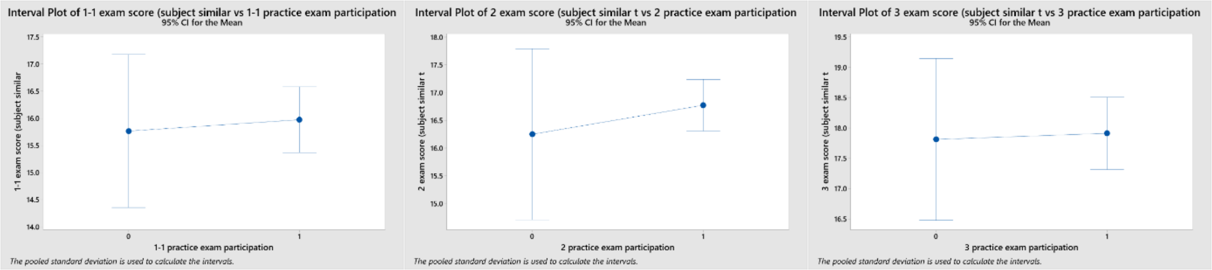


Figure 6. Heat Transfer. Comparison of participation in practice exam to actual midterm 1 grade (left), midterm 2 grade (center), and midterm 3 grade (right).

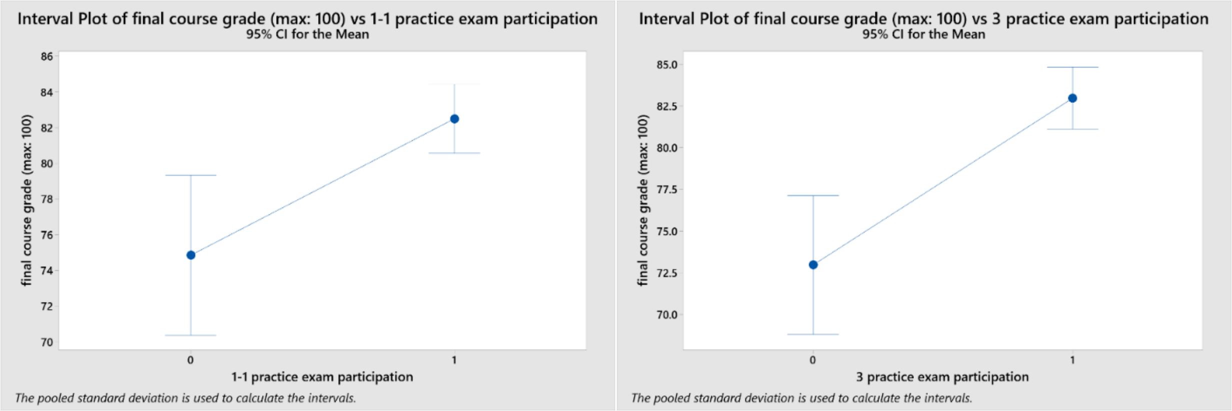


Figure 7. Heat Transfer. Participation in 1st midterm practice compared to final course grade (left). Participation in 3rd practice exam compared to final course grade (right).

Conclusions

The data shown here answer the first research question with a qualified yes. Younger students benefit from participation in practice exams, which agrees with education research and engineering education research findings. Younger students may benefit from more structured study activities such as practice exams. Upperclassmen participated to a greater extent than underclassmen in practice exams, but there was no significant effect on any individual exam score.

The data shown here answer the second research question with a definite no. For younger students in thermodynamics, the score on the practice exam is not statistically significant with actual exam score or overall course grades. Also, from the dynamics students' data set, we find that practice exam questions that are poorly aligned with actual exam questions (difficulty of analysis) are not useful predictors of actual exam performance.

The data shown here answer the third research question again as a qualified yes. For underclassmen in thermodynamics, the effect size is about 1 letter grade increase. Upperclassmen who participated in practice exams had a statistically significant increased likelihood of a higher overall course grade, also about 1 letter grade. However, upperclassmen may have developed overall more mature and effective study habits, not only for exams but also for projects.

Some useful general conclusions can be drawn about the data presented here and the formative feedback method presented here. First, formative feedback is beneficial to students, though the effect size (grade improvement) may vary depending on the students' classification (i.e., 1st year vs. senior). Second, the literature review from education research shows that there is ample opportunity for improving the formative feedback style, and online tools such as Canvas are already designed to provide pop-up feedback based on student responses. Third, students will participate, regardless of the course credit earned, and professors can actively show that they care about their students' learning process. Lastly, engineering educators should adopt some form of formative feedback in their courses, especially for younger students, especially for exams.

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