The Success and Retention of Students Using Multiple-Attempt Testing in Fundamental Engineering Courses: Dynamics and Thermodynamics

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The Success and Retention of Students using Multiple-Attempt Testing (MAT) in Fundamental Engineering Courses: Dynamics and Thermodynamics

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Abstract

The impact of multiple-attempt testing (MAT) on students' overall success and retention in fundamental engineering courses was studied when implemented in a blended mixed-mode (M-mode) class where students were given simple assignments before class. Two engineering courses were delivered in M-mode in Spring 2023 (post-COVID): Dynamics and Thermodynamics, whose results were compared to the same courses given in the same semester, four years earlier, delivered in M-mode in Spring 2019 (pre-COVID). All four courses were large classes of 167 students in Dynamics to a maximum of 245 in Thermodynamics.

All courses had three tests during the semester conducted in the Evaluation Proficiency Center (EPC). In Spring 2019, students were given a five-day window per course to take their tests. Facilitated by the Learning Management System (LMS), the grades were instantly uploaded into the LMS CANVAS. Once the test closed, students were allowed to see their work with a teaching-assistant (TA) to learn from their mistakes and claim some partial credit where possible. However, in Spring 2023, for both courses, students were given three tests during the semester with *three possible attempts per test*, as well as an *optional final* comprehensive exam, also *with three attempts*. All attempts were optional for those who wanted to ameliorate their scores, be it for the tests or the optional final examination. No partial credit was given in any attempt of any test or the final exam for Spring 2023. Each attempt was open for two days and the students were allowed to identify their mistakes with their TA, learn from them and prepare better for the next attempt.

The effectiveness of this testing-interwoven-learning method lies in the comfortable and less anxious ambiance for the students to do their tests knowing they have other chances. They could learn from their own mistakes, focus their attention on their weaknesses, and enhance their knowledge to do better in the next attempt. Proven by substantiated results, this self-paced method permits the students to learn a lot on their own.

The study shows a substantial decrease in the failure rate, and the overall DFW rate, which decreased by more than 40% in both courses. Students aspired to do well in every attempt, and even when they failed all three tests, they would still have an optional final examination that could prevent them from failing, which further reduced the overall DFW rate. While previous work has shown that the method is effective, a new survey was conducted to assess students' perceptions of this testing method as well as their self-reported motivation and use of self-regulated learning strategies, revealing more than 70% of students reported, "liked" this method of testing.

Keywords: Multiple-Attempt Testing, Large Dynamics Classes, Students' success and retention.

Introduction

The abrupt transition in education expectations from high school to college leaves some students confused and bewildered on how to prepare for their tests and exams. In fact, the digital support of some websites, such as Chegg[1] and artificial intelligence (AI) websites such as ChatGPT[2] can be very useful in the students learning. However, they could also be used as cheating hubs as pointed out by M. M. Lanier[3] , A. Fask et al.[4], as well as P. Charlesworth et al.[5] , for the students to merely earn better grades without making real efforts. It is evident that the more effort the students exert on their assignments, the more likely they will score higher in their tests (Arora, M. L., Rho, Y. Jin, & Masson, C.[6]). Unfortunately, some students still may not do well on their tests or exams even after many hours of preparation due to a few reasons. Some of these are, anxiety, confusion, lack of confidence or concentration while learning the material or during a test.

As a training medium, the McGraw Hill Connect[7] has an option that permits the students to repeat the assignments multiple times. If used consciously, this could be an effective learning process and a tool for preparing well for the tests, while strengthening their knowledge in foundational courses, (K. K. Archer[8]). As per the instructor's experience with large classes, in some student's mind, "it is only an assignment, and I am allowed to do anything, for as long as I submit it on time and get a high grade. I can study for the test later", but *that later* never comes! Moreover, the illusion of having scored high in an assignment often misleads the students into thinking they learned well, Nader et DeMara[9]. Many a time students would complain to the instructor that they worked hard, but they still scored poorly relative to their knowledge.

One solution to the above issues is giving the students the chance to take their tests more than once as per G. Herman[10], rather than just the assignments as in McGraw Hill Connect. In other words, let the students repeat the test with different questions and problems. Nader and DeMara[9] proposed a new approach that allows the students to take a test with multiple attempts and review their mistakes between those attempts. They found that the students progressively learned materials better and scored higher. The method opened a possibility of utilizing a digital platform to do the same. Unfortunately, unproctored remote online digital examinations may come with inflated grades, threatening the integrity of the tests as a whole, as reported by M. M. Lanier[3], A. Fask et al.[4], and P. Charlesworth et al.[5]. Using an online proctoring tool such as Proctor Hub or LockDown Browser with Respondus may be considered as an alternative. However, close and continued monitoring of student behaviors during the tests in large enrollment classes remains challenging. What about internet outage for a few minutes? The system allows them to come back to the test for as long as the test is still running. It is, therefore, necessary, and more suitable to standardize the test setting. To address these issues, a proctored digital environment in a designated physical space, such as the EPC [11], is most suited for this process.

The EPC Testing Environment

The EPC is open daily for testing from 9:00 AM – 9:00 PM with 130 comfortable seats. Each of which is provided with a computer allowing asynchronous examination, in which case students would have to choose a time slot among a few days to complete their tests. Each station is equipped with Lockdown Browser restricting the students from checking the internet or communicating with a third party for help. Moreover, the EPC has 16 cameras with proctoring TAs as well, to ensure a secure examination environment with integrity and void of cheating. As soon as the students step into the EPC, they enter a locker room where they put their belongings. With their ID cards they are admitted into the examination hall where they are provided with scratch sheets, to write their solutions on, which they are required to bring back to scan for future records. On the scratch sheets, they write their names, ID, course number, and the test date. The students are allowed to bring in a pencil/pen, while the EPC provides standard calculators. They are usually given enough time to take their tests and at the conclusion of their tests, the CANVAS LMS[12] system instantly and automatically grades these tests and allocates a numerical score for each student.

In general, the students would meet their TAs in a separate room within the EPC, to see where they went wrong, and to learn from their mistakes. The students can see what they wrote down on their scratch sheets as well as the questions on the computer with their answers. With only one attempt, the students would come to the EPC to explain where they went wrong and would be given some partial credit, after the permission of the instructor. However, the maximum extra points would be typically 10% of the whole score, to encourage the participation in this review to foster their learning without mitigating the integrity of the test procedure. In the case of MAT, the students would come to the EPC to see where they went wrong and to get feedback on what they did, to improve their learning and do better in a subsequent attempt.

The EPC provides an ambiance of integrity to avoid any grade inflation. The advantage of the digital examinations is the facilitation of the MAT that would otherwise be cumbersome and time consuming if performed traditionally on-paper. The EPC standardizes the test settings.

Course Delivery

Although the courses are very close in their delivery method, they are not perfectly aligned in style. For example, Dynamics of Spring 2019 was officially a regular face-to-face class with a weekly two-day lecture, yet all the material and the course style were very similar to that of the M-mode. Thermodynamics of Spring 2019 was delivered as M-mode. In both courses the tests were allowed with one attempt per test in the EPC. However, in Spring 2023 both courses were delivered in M-mode with three attempts per test. The details are explained below.

Dynamics & Thermodynamics Spring 2019 – Pre COVID, Single Attempt Testing (SAT)

Prior to COVID-19, both courses included three tests with only one attempt per test. Although Dynamics was given via a in-person two-day class lecture (i.e., three hours per week), all the material was prepared as an M-mode class. The M-mode style was such that there were initially 252 students in this Dynamics course who were given access to YouTube videos, pre-prepared by the instructor with pertinent homework focused on the material based on the book by P.J. Cornwell et al.[13] Part of their pre-assignments was also the adaptive learning LearnSmart (LS) homework. The combined effect between the LS and the video homework were believed to have had prepared the students for the lectures, during which some problems were solved in class before the rigorous assignments.

Similarly, the Thermodynamics course M-mode style was such that the 241 students were given YouTube videos with pertinent homework questions and LS to prepare them for the lectures. During the lectures, the material was briefly emphasized and questions about the concepts were discussed and answered, and more examples were solved. Being M-mode, the weekly 1.5 hour lectures were mostly reserved for solving problems since in the videos the concepts were explained with some simple examples. After the class was over, students were ready to solve the more rigorous assignments.

Note the fact that for the regular Dynamics course, the students came to class twice a week with all the benefits of the videos that were available 24/7 of an M-mode class, it could be said they had an advantage over the students in a similar Dynamics class who only had half of the contact hours with their instructor as in Spring 2023. Moreover, in both classes, students were allotted 90 minutes per test for Spring 2019, which is more time than those given in Spring 2023, 75 minutes for the same number of questions pulled randomly C.J. Lee [14] from the same question banks.

Note also, in the Dynamic course the students were given low stake quizzes a week before they would do their tests to check their understanding of the content i.e., the formative test as in Nader et al[11], and know how much more they should prepare before their tests. However, the quiz questions were obtained from much smaller banks than those of the regular tests. Note, for *both* Spring 2019 courses, all the quizzes and tests were conducted in the EPC and the best 2 out of 3 test scores were considered for the final grade. Given the large class, this was a system with a contingency plan for those who would get ill, hospitalized, death in the family, and the like. Unfortunately, that encouraged a good percentage of students to skip any one test which would not impact their final grades (Figures 2 and 3). With this condition, students in these two courses likely did not persevere until the end, i.e. a lot of them ignored the last test, knowing that with the first two tests they were already passing the course.

Dynamics & Thermodynamics Spring 2023 – Post COVID, Multiple Attempt Testing (MAT)

Post COVID-19, MAT was considered in both courses. Both Dynamics and Thermodynamics courses of Spring 2023 ran in parallel and were both delivered as M-mode classes, namely, between the Spring 2023 and the Spring 2019 classes. For example, in Spring 2023, the only

homework given before the lecture was the SmartBook (SB), formerly known as LS. YouTube videos were provided to the students, but no video homework was assigned so students would not fast forward through the videos to find the answers to their homework questions, thus defeating the purpose of learning. To entice the students to watch all the videos, a new style was adopted for Spring 2023 classes. Students were asked to take notes while watching these videos at home and then come to class prepared. In class, very short quizzes of about 3 minutes were given based on those videos to test whether the students watched them before coming to class. Since the students were aware of these quizzes, they were expected to prepare better before coming to class. Notice that the rigorous assignments during the Spring 2023 semester were bundled up as 2, 3 or up to 5 at a time and were due a day or two before the first attempt of each test to allow for review when the solutions were given out. This style gave the students time to learn from the mistakes they had made just before they sit down for the test, and it also fostered self-paced learning given the fact that they had five to six weeks to submit the bundled assignments within the limit of that deadline.

The tests were very similar to the previous Spring 2019 courses such that the number of questions given in each test were the same. However, the time allotted was reduced to 75 minutes from 90. The average amount of time needed to conduct the test obtained from Spring 2019 tests provided by CANVAS was about 75 minutes, in which case the students of Spring 2019 were privileged in comparison, by being given more time.

To ensure tests qualities and fairness for all, the question banks were designed and created carefully such that there were easy question banks with simple conceptual questions, another with simple calculation problems, a third with slightly difficult problems, and a fourth with more complicated problems. At times more than one question is pulled from the same question bank. Each test comes with a very similar difficulty for each student. As such, no students complained. In Dynamics, for example, there are about 250 problem banks for the first test alone, not to mention the replications the computer generates, which is about 90 problems for each question. Out of these banks, each student gets about ten questions per test. As such, with that many problems, cheating is difficult to achieve even when the test is open for a week. Another approach to ensure thorough examination is the variation in question styles, not only confined to multiple choice type Marsh et al.[15], the questions styles come with multiple drop-down, True/False, numerical calculations without ignoring the simple conceptual questions, and simple calculations T. Tian & R. F. DeMara[16].

In the case of Spring 2019 students were allowed some partial credit if they came to the EPC to see their tests and explain how they approached the problem. However, that route required a lot of effort and patience from the TAs, as the students spent a lot of time trying to see a way to ask for extra credit, which if proven right, the issue would be brought up to the instructor to compensate the student with the extra credit.

Post COVID and with MAT, the partial credit was made no longer available, to avoid student negotiations. Instead, they were given three attempts per test. In fact, they were also given a final cumulative exam, which would help the students who failed all the tests during the semester and would still give them a final chance to pass, similar to that done by Nader & Dziuban[17]. This is a last call support instead of the best 2 out of 3 tests performed in Spring 2019. The final exam of Spring 2023 also came with three attempts.

With the MAT of Spring 2023, the EPC provided a six-day window of testing. Based on a two-day attempt, the test could be completed with up to three attempts. After each attempt the students could meet up with their TAs in a separate room within the EPC, to see where they went wrong and to learn from their mistakes. With the next attempt, it was hoped the students would not repeat the same mistakes, thus allowing the students to improve their grade. This process gave students a lot of hope, and put them at ease, at least in their first and second attempts, preventing anxiety so the students were comfortable expressing their knowledge of the material during the attempts. Out of the three attempts, the highest mark was retained. The two-day window is a better approach of learning than students cramming three attempts in one sitting, thinking that they could depend on their luck on what problems would come in the test given, say, they prepared for certain types of problems. The fact that the students were allowed to see their TAs before their next attempt was a tease, as in, "What if I get the same problem in the test, would I be able to solve it?" Some problems do repeat themselves, but with different numbers. If the students *learned* from their mistakes, they would get that repeated question right. Again, the two-day window per attempt in this case also allowed for self-paced learning within the limit of the six-day window per test.

Student Surveys

Evidently, the three attempts benefit student outcomes on these examinations. To bolster understanding of these methods, we further investigated student perceptions of multiple attempts and their effectiveness in their course. A 10-item self-report survey was administered to collect data on students' perceptions of MAT (e.g., *MAT helped me take the test with less stress knowing I have other chances*; *it gave me the chance to recognize how much more I should study before my next attempt*; *it allowed me to do better in the course*) on a Likert scale from 1-5 (Strongly disagree (1) to Strongly agree (5)). For Thermodynamics, we collected data before their first test (Entry) and after their last test (Exit); we obtained 131 responses (n = 131) for both tests for all questions. As we were unable to collect student identifiable information, we investigated how mean student scores changed across the semester.

Descriptive statistics reveal that, on average, 59% (83 out of 141) of students reported that they agreed or strongly agreed with the statements about the usefulness of MAT *before* testing, whereas agreement with these statements increased to 74% (114 out of 153 students) *after* the last test. A two-tailed paired-samples t-test was conducted to examine changes in perception of MAT from Entry to Exit responses. Results reveal that 8 of the 10 survey question items show a significant change ($p < .05$) from Entry to Exit as in Table 1, demonstrating that students expressed more agreement with the MAT later in the semester, Figure 1.

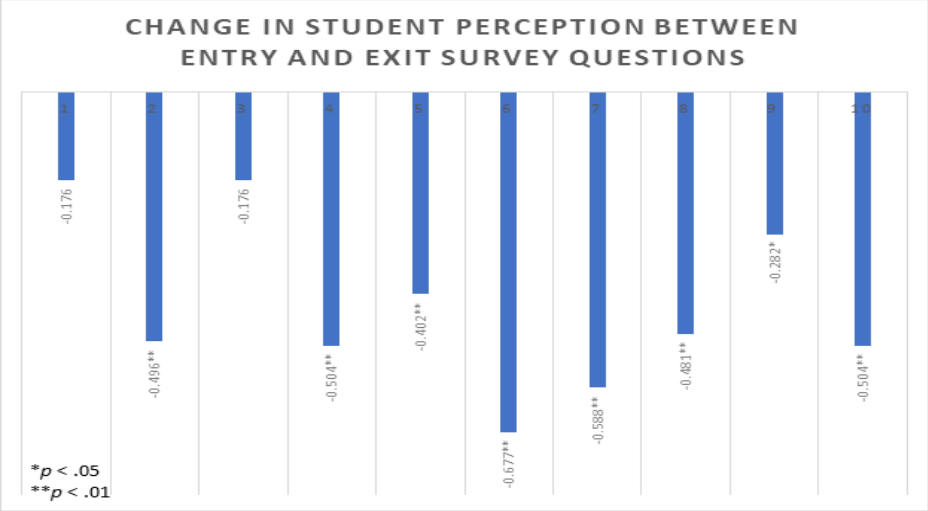

Figure 1.: Change in Student Perception Before and After MAT

Table 1. Paired-Samples *t*-Test Results for Thermodynamics.

Survey Item All items start with multiple attempts...	m_{entry}	m_{exit}	Dm	*p*
1 – Helped me take the test with less stress, knowing I have other chances.	3.80	3.94	-0.137	0.393
2 – Allowed me to go back to learn the material better before my next attempt.	3.76	4.25	-0.496	0.000
3 – Gave me the opportunity to know where I stand in the course before my next attempt.	3.71	3.89	-0.176	0.278
4 – Gave me the chance to recognize how much more I should study before my next attempt.	3.71	4.21	-0.504	0.000
5 – Gave me the chance to repeat just the test instead of repeating the entire course.	3.80	4.20	-0.402	0.004
6– Allowed me to do better in the course.	3.44	4.12	-0.677	0.000
7 – Was not helpful because no matter how much I tried, I still got the same grade (REVERSED)	2.30	2.89	-0.588	0.000
8 – The fact that I could go back and ask about a problem I saw in the test to study it before my next attempt advanced my knowledge of the subject, even though I knew it might not show up in my next attempt.	3.56	4.04	-0.481	0.001
9 – I learned a great deal with this testing method, irrespective of my grade.	3.53	3.82	-0.282	0.050
10 – In the future, I hope to see more courses offered with 3-test attempts that allow a full week to complete.	3.66	4.17	-0.504	0.001

Note: m_{entry} are the average values for the Entry Survey. m_{exit} represents the average values for the Exit Survey. D_m is the difference between the two mean values.

Data and Results

As explained earlier, in Spring 2019 the best 2 out of 3 tests were considered in each student's final grade. With this curve, the results are shown below in Figures 2 and 3, for both Spring 2019 courses. Note that the number of participants fall sharply by Test 3 (T3) and the overall number of students passing these tests are about the same, 38% and 37% for Dynamics and Thermodynamics, respectively, while the class averages are different. The likely reason why some students did not take T3 is because they knew they did well in the first two tests and that one of three of these tests would not count toward their final grade. Therefore, they excused themselves from taking the last one, leading to a much lower percentage of participation and an overall lower average.

	T1	T2	T3	Overall Test Mark
Class Average	61%	63%	53%	42%
No. Student Success >70%	48%	50%	19%	38%
Participant	95%	95%	38%	100%

Figure 2.: Class Average and Success Rates for Dynamics Spring 2019

	T1	T2	T3	Overall Test Mark
Class Average	56%	56%	54%	62%
No. Student Success 70%	30%	31%	27%	37%
Participant	100%	97%	53%	100%

Figure 3.: Class Average and Success Rates for Thermodynamics Spring 2019

While comparing the results of the two sets of Spring courses (2019 vs 2023 courses), the results of Spring 2023 should be noted. Figure 4 shows the effect of MAT with a clear overall improvement per attempt in each test. The trend is always oriented positively upwards. Figure 5 illustrates the results of those who chose to take the final examination as compensation for their inadequate performance during the semester in all three tests. A similar upward trend is also shown with a higher-class average and a higher success rate in all the attempts.

	T1				T2				T3			
	A1	A2	A3	Best of 3 Attempts	A1	A2	A3	Best of 3 Attempts	A1	A2	A3	Best of 3 Attempts
Class Average	44%	56%	65%	68%	40%	55%	63%	67%	45%	36%	60%	58%
Success >70%	10%	28%	45%	54%	10%	32%	42%	51%	11%	2%	26%	27%
Participants	100%	94%	77%	100%	100%	94%	65%	100%	100%	89%	64%	100%

Figure 4.: Class Average and Success Rates for Dynamics with 3 Attempts per Test Spring 2023

	Final Examination			
	A1	A2	A3	Best of 3 Attempts
Class Average	31%	44%	53%	49%
No. Student success >70%	2%	9%	15%	15%
Participants	100%	85%	63%	100%

Figure 5.: Class Average and Success Rates for Dynamics 2023 Final Exam with 3 Attempts

In the optional final exam of Dynamics of Spring 2023 class, out of 65 participants, 30 (i.e. 46%) improved their overall grades as shown in Figure 6 below. These 30 participants improved their grades by 20% on average leading to a higher percentage of students' success of 8.7%, i.e., from

42% to 46% of the class obtained 70% or greater in the courses' tests/exam. In other words, 15% of those who participated (65) in the final examination passed. This is equivalent to 10 extra successful students in this course out of 167, or 6% of the whole class.

	Three Tests Results vs Overall Examinations Grades			
	Three Tests	Final Exam	Overall	Overall Improvement, Average or Student Success
Class Average	62%	49%	64%	2.6%
No. Student success >70%	42%	15%	46%	8.7%

Figure 6.: The Best of Three Tests or a Final Cumulative for Dynamics Spring 2023

As expected, the results are similar in Thermodynamics, Figure 7 shows the positive upward trend in almost all attempts between the three tests and the final examination, as in Figure 8. We notice also, that in all of Figures 4, 6, 7 and 8 the number of participants decreases in every attempt. That is because some students were satisfied with their marks from the first attempt. Others, still wanted to improve their grades with a second attempt and finally there are those who wanted to continue till the end so they could pass or get a better grade.

	T1				T2				T3			
	A1	A2	A3	Best of 3 Attempts	A1	A2	A3	Best of 3 Attempts	A1	A2	A3	Best of 3 Attempts
Class Average	47%	54%	60%	66%	51%	65%	76%	75%	49%	59%	66%	69%
Success >70%	17%	25%	36%	49%	15%	46%	74%	72%	11%	27%	49%	54%
Participants	100%	92%	70%	100%	100%	91%	68%	100%	100%	85%	64%	100%

Figure 7.: Class Average and Success Rates for Thermodynamics with 3 Attempts per Test Spring 2023

In all these figures (4, 6, 7 and 8), one cannot help, but notice that the best of 3 attempts may not be a number that is anything like any of the attempts, A1, A2 and A3. In fact, at times one may notice it is even less than at least one of them, especially less than class average or the students' success rate. The reason behind this is that the best score is kept from each attempt and depending on the number of participants these numbers vary. Note also, that the best of 3 attempts means this is the overall class average or the maximum student success rate for that test. For instance, Figure 7 depicts that in Test 2 (T2), the class average for that test was 75% and the number of students that passed that test, i.e. those who obtained 70% or greater, was 72% of the class.

	Final Examination			
	A1	A2	A3	Best of 3 Attempts
Class Average	51%	52%	62%	57%
No. Student success >70%	12%	8%	34%	26%
Participants	100%	66%	36%	100%

Figure 8.: Class Average and Success Rates for Thermodynamics 2023 Final Exam with 3 Attempts

In Thermodynamics of Spring 2023, out of 90 participants, 44 (i.e. 49%) improved their overall grades as shown in Figure 9 below. These 44 participants improved their grades by 25% on average leading to a higher percentage of students' success of 8.9%, i.e., from 51% to 56% of the class obtained 70% or greater in the courses' tests/exam. . In other words, 26% of those who participated

(90) in the final examination passed. This is equivalent to 23 extra successful students in the course out of 242 remaining students, or close to 10% of the whole class.

	Three Tests Results vs Overall Examinations Grades			
	Three Tests	Final Exam	Overall	Overall Improvement, Average or Student Success
Class Average	67%	57%	69%	2.9%
No. Student success >70%	51%	26%	56%	8.9%

Figure 9.: The Best of Three Tests or a Final Cumulative for Thermodynamics Spring 2023

Now comparing Spring 2019 and Spring 2023 courses, we notice the difference in the overall class averages and students' successes, given the same tests banks, with less allotted time for each test in Spring 23, 75 min vs 90 min for Spring 2019. Figures 10 and 11 depict the bigger pictures for the comparison between the tests' styles, between the SAT and the MAT. As in Figure 10, the success rate in dynamics is 20% higher for Spring 2023 due to MAT, yet the class average has improved much more, 52%. The fact that the class average improved from 42% to 64% indicates that a lot of students were close to passing these tests, but mostly passed the course given the assignments. Figure 11 clearly shows the improvement in students' success in these tests by 49%, indicating that close to a half more students succeeded in these tests or the final exam. The testing style change from SAT to MAT has improved the students' performance and knowledge. It gave them opportunities to persevere to achieve the better grades.

	Overall Test Mark		
	Spring 2019	Spring 2023	Improvement
Class Average	42%	64%	52%
No. Student success >70%	38%	46%	20%

Figure 10.: Comparison between SAT and MAT for Dynamics Course

	Overall Test Mark		
	Spring 2019	Spring 2023	Improvement
Class Average	62%	69%	11%
No. Student success >70%	37%	56%	49%

Figure 11.: Comparison between SAT and MAT for Thermodynamics Course

Overall Student's Success

At this stage one may ask, what is the overall performance in class, given the above changes and students' success? Figures 12 and 13 depict the overall grades for each course, illustrating the increase in As and Bs, the overall percentage pass grades and DFW between the Dynamics classes of Spring 2019 and Spring 2023, as well as the Thermodynamics classes, respectively. In the first case, i.e. in Dynamics as in Figure 12, the students' higher success of As and Bs increased from 44% to 66%, the pass rate increased from 67% to 80% and the unsuccessful rate decreased from 33% to 20%. Similarly, Figure 13 shows that in Thermodynamics, the students' success of As and

Bs more than doubled increasing from 37% to 78%, the pass rate increased from 62% to 87% and the unsuccessful rate decreased from 34% to 13%. This is likely because students were given other chances in MAT. Given the large test banks, the students were tested on the same topics with different questions, while the students are better prepared given the feedback in between attempts and the extra opportunity of making more attempts.

Dynamics Spring 2019 - 252 Students					**Dynamics Spring 2023 -167 Students**				
Grades	No. Of Students	Class Percentage			Grades	No. Of Students	Class Percentage		
A	45	18%			A	54	32%		
B	65	26%	**44%**	**As&Bs**	B	56	34%	**66%**	**As&Bs**
C	58	23%	**67%**	**Pass**	C	24	14%	**80%**	**Pass**
D	20	8%			D	10	6%		
F	48	19%			F	11	7%		
W/WM	16	6%	**33%**	**DFW**	W/WM	12	7%	**20%**	**DFW**

Figure 12.: Overall Results Comparison between 2019 and 2023 Dynamics Courses

Thermodynamics Spring 2019 - 241 Students					**Thermodynamics Spring 2023 - 245 Students**				
Grades	No. Of Students	Class Percentage			Grades	No. Of Students	Class Percentage		
A	20	8%			A	107	44%		
B	74	29%	**37%**	**As&Bs**	B	84	34%	**78%**	**As&Bs**
C	61	24%	**62%**	**Pass**	C	22	9%	**87%**	**Pass**
D	33	13%			D	9	4%		
F	35	14%			F	11	4%		
W/WM	17	7%	**34%**	**DFW**	W/WM	12	5%	**13%**	**DFW**

Figure 13.: Overall Results Comparison between 2019 and 2023 Thermodynamics Courses

	Dynamics	**Thermodynamics**
As &Bs Improvement	51%	109%
Overall Pass Improvement	20%	41%
Retention increase	**41%**	**61%**

Figure 14.: Overall Results Comparison between 2019 and 2023 Dynamics Courses

Figure 14 summarizes the comparison between the two sets of courses. In Dynamics, the higher success of As and Bs translated to 51% increase, but more than doubled in Thermodynamics, precisely, 109%. The increase in the overall passing rates in these courses are 20% and 41%, respectively. More importantly, what is the increase in the retention rates? As shown in Figure 14, it increased by 41% for Dynamics while 61% for Thermodynamics. In other words, the unsuccessful rate has been down by about half for both courses.

Discussion

In comparison to SAT, MAT gives multiple chances to students to learn from their own mistakes and failures until they finally learn the material by remedying their weaknesses before they proceed to upper level classes. Though the weaker students learn from their mistakes and eventually pass the course, the strong students still become stronger by enhancing their knowledge. It gives more chances to everyone including Transfer Students (TS), Cedja, Hills, Lakin & Elliot as well as Smith et al.[18-21].

Significant results of students' grade improvement are reported when Dynamics of Spring 2019 (Pre-COVID-19) is compared to that of Spring 2023 (Post-COVID). The total percentage of As and Bs increased by 51% in Dynamics and similar results were obtained for Thermodynamics, 109%, owing to the MAT method, in addition to the optional final exam that also came with MAT. The overall passing grades were 20% more in Dynamics and 41% in Thermodynamics while the retention rate increased by 41% and 61%, respectively.

The MAT of the final examination bumped up about 6% more students in Dynamics versus close to 10% in Thermodynamics to pass the class. The improved class average rate of the students mark for Spring 2023 with the help of the optional final exams were also 20% in Dynamics and 25% in Thermodynamic. Note that students' final grade can be calculated in two ways, either all the tests added together (T1+T2+T3 = 75 points, i.e., 25 points each) **or** the optional cumulative final exam (Total out of 75 points). Therefore, if a student scores an average of 50% on the tests, but scores 65% in the optional final exam, they would score 65% on the testing portion of the course. Although this is still less than a testing passing grade of 70%, the increase from 50% on the tests to the 65% in the final exam still demonstrates an improvement. This 65%, when added to the assignments, increased the possibilities of the students succeeding in the course as a whole. Thus, at least the students who failed marginally on the testing portion would be able to remain in the program.

The method requires a digital setting, though online is possible, it is more trustworthy in an examination center with LockDown Browser and proctors to assure the integrity of the exam with no grade inflation, A. Fask et al.[4]. The students also take the exam more seriously and prepare well in such conditions, knowing there is no Chegg or AI websites to help them, so they work harder to gain their grades. This method seems effective regardless of the course being taught, who teaches it or the exam type, provided that more opportunities are available to the students in general. It may appear easy to pass the course with this method for some observers, but our study shows otherwise. Some students tried hard in vain because they did not focus on learning rather memorizing. In fact, well-structured MAT necessitates students to gain the fundamental knowledge to solve the problems to pass the course with this assurance in their minds - if I fail, I have another chance to succeed after learning more!

Conclusion

The MAT has proven to be an effective assessment method interwoven with students' learning process. It *decreases the students' anxiety* knowing they have other attempts. It *scaffolds* their learning L. A. Fish[22] by reviewing their weaknesses with TAs after each attempt to fine tune their knowledge before the next attempts. It encourage them to *persevere their learning* and *do better* in their tests as they progress through the attempts. It allows the students to *steer their learning* by making them focus on what they do not know and improve their knowledge of the subject to fulfill the course requirements. In addition, it is *self-paced,* within the limits of the bundled assignments deadlines and the week of testing, it teaches the students to *autonomously learn by repetition with a goal*, a technique they can take with them to upper level classes, without the need to be assisted by others any longer. It, therefore, acts as a *training tool*. It functions as a *hub of testing and learning* fostering a *friendly education ambiance that effectively reduces student anxiety*. In essence, it produces a higher success and retention rate by all of the above.

It has already been tested to work well for transfer students, Nader et al.[24] boosting their grades well comparable to First Time in College students, circumventing issues caused by transfer shock by virtue of the more chances it gives. It has, therefore, partially resolved issues related to curriculum alignment also due to the generous opportunities given by the multiple attempts, allowing the students to close the knowledge gap they had before the transfer. And recently, it has been tested by different instructors to prove the effectiveness and functionality of the method, regardless of the instructor, Nader & Qiushi[25].

When asked about MAT, the students show their satisfaction with its effectiveness, seeking to see this method utilized in other classes as well. The survey indicates that 74% agreed it is beneficial. Furthermore, after conducting a paired *t*-test, results reveal that 8 of the 10 survey question items show a significant change ($p < .05$) from Entry to Exit (see Table 1), demonstrating that students expressed more agreement with the MAT's effectiveness later in the semester (see Figure.1). These results demonstrate that once students engaged in this new testing/learning approach throughout the semester, the more students agreed or strongly agreed with the benefits of MAT.

Future Work

The method may not be new but has not yet been investigated thoroughly. It appears it is still in its infancy. More studies on students with different demographics and stages of learning in other engineering courses should be investigated. How effective is it with students with disabilities and how could it be improved to fit different types of learning styles? How are the success and retention rates associated with a specific group of learners? A group of researchers may be required to continue investigating various angles of the proposed method including but not limited to what other factors could be used, and what potential improvements can increase its effectiveness.

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