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From Strategy to Setback?: How a New Teaching Method Affected Exam Outcomes in an Engineering Course

Dr. Eleazar Marquez, The University of Texas Rio Grande Valley

Eleazar Marquez is an Assistant Professor of Practice in the Department of Mechanical Engineering at The University of Texas Rio Grande Valley.

Dr. Samuel Garcia Jr., NASA EPDC

Dr. Samuel GarcÃa Jr. serves as a NASA Educator Professional Development Specialist at Kennedy Space Center. Dr. GarcÃa helps facilitate professional development to both formal and informal STEM educators utilizing NASA resources with a specific focus o

From Strategy to Setback?: How a Change in Teaching Method Affected Exam Outcomes in an Engineering Course

Research indicates that student learning, engagement, and success in engineering education is highly attributed to the classroom environment and incorporating visual supplements to enhance the physical understanding of fundamental concepts. Despite the implementation and success of numerous pedagogical strategies in these domains, many universities across the country continue to struggle with retention rates, both at the institutional level and the college of engineering. To address these challenges and promote student success, the authors of this study explored an alternative pedagogical approach in a Rigid Body Dynamics course at a Hispanic-serving institution. Since the course has a demanding curriculum, the strategy was to reuse homework and lecture problems on exams. In this regard, step-by-step homework solutions were concurrently provided for each assignment. The objective was to 1) offer a comprehensive resource for students to fully grasp each course concept; 2) promote student success; 3) improve passing rates in the course: and 4) minimize the risk of students violating the honor code. The primary focus of the study was to test the effect of incorporating homework problems or lecture notes problems into each of the four in-class exams throughout the semester. This was done to assess whether such integration could influence student performance. The effectiveness of this strategy was evaluated by comparing exam results across semesters. Interestingly, the analysis suggests that exam averages were lower in the semester when the step-by-step solutions were provided concurrently for each homework assignment compared to semesters where this strategy was not implemented. The effectiveness of this strategy was evaluated during each examination. Unexpected results indicate that exam averages were lower than those semesters when the solutions were not provided concurrently for each homework assignment. The average for exam 1, exam 2, exam 3, and the final exam during the Spring 2023 semester (solutions provided) included: 57.1, 59.6, 55, and 55.2 respectively; while the averages for Spring 2022 semester (solutions not provided) included: 81, 69, 73, and 74 respectively; and the averages for the Fall 2022 semester (solutions not provided) included: 71.6, 70.78, 61.5, and 62.05 respectively. The drastic decline in exam scores revealed that 1) providing the solutions concurrently with the homework assignment may be harmful to the overall student success in engineering education, 2) students are not allotting time to understand the step-by-step homework solutions, 3) students are memorizing solutions rather than understanding, and 4) violating the honor code is definitely not the best option for success. This study underscores the importance of critically evaluating teaching methods to ensure they promote genuine comprehension and academic success, particularly in demanding fields like engineering.

I. BACKGROUND AND MOTIVATION

Pedagogical Strategies

Extensive research has demonstrated there are a myriad of factors that affect student learning and attainment. For instance, classroom environment, encompassing the tone, climate, and overall ambience, significantly affects student engagement, learning, and success in engineering education are various factors that affect student learning. To this end, problem-based learning (PBL) [18], project-based learning [19], [20], and visual cuing [21], [22], [23], [24] are well-documented and effective pedagogical practices commonly implemented in a classroom setting to address student outcomes. From these pedagogical methods, the most impactful towards strengthening student learning, engagement, and attainment is classroom environment [5], [6], [7], [18], [25].

In this regard, research underscores the significance of the psychosocial aspect of the classroom, which integrates psychological factors with the social environment to enhance educational productivity [2], [3], [4], [5], [6], [11], [13]. A positive classroom climate fosters diverse learning styles and promotes academic development, underscoring the need for educators to prepare and deliver lecture content with clarity, technical rigor, and an inclusive structure [14].

To this end, various communication methodologies have been designed and implemented for educators use [2], [3], [4], [5], [6]. Marquez and Garcia developed a model termed ECNQ (acronym for Engage, Communicate, Names, Questions), which allows the instructor to engage in four communication strategies that remove intimidation barriers between student and faculty member, and simultaneously foster an intellectually rich and healthy environment by encouraging student participation during lecture sessions, communicating with students before and after class, learning student names, and posing non-intuitive questions to spark curiosity [5]. Marquez and Garcia developed and implemented a model termed CIRE (e.g., acronym for Communication, Initiation, Reduction, and Extension) during COVID-19, which is a template recommended for online instruction [17]. The model recommends instructors maintain constant communication with students, initiate homework problems during lecture sessions, reduce the number of problems on homework and exams, and grant extensions on homework assignments when deemed appropriate [2]. Furthermore, research by Murnane, Summers, and Wolf indicates that teacher characteristics play a pivotal role in student learning and achievement [8], [9]. Effective teaching, characterized by clarity, consistency, and alignment with institutional academic standards, has been identified as a common denominator in high-performing schools [1], [7], [14], [15]. Teachers who align their pedagogical strategies with established academic standards contribute to improved student achievement and institutional success.

Alternate Pedagogy: Reuse of Questions on Exams

Despite implementing communication strategies as a mean to strengthen student outcomes, engagement, and attainment, researchers have considered alternative pedagogical schemes to reach equivalent results. Innovative teaching methods have emerged as a critical factor in enhancing skills-based subjects such as engineering and technology. According to Naz and Murad (2017), innovative pedagogy is rooted in the belief that every learner has the potential for success when provided with the appropriate tools and strategies. These teaching methods recognize the unique personality characteristics of each student and leverage these traits to optimize learning outcomes [14]. This has led to deliberate efforts by engineering faculty of piloting and experimenting with modifying existing and/or implementing instructional strategies and approaches influenced by the contextual realities of students. Moreover, researchers Santosa et al. (2019) emphasize the effectiveness of innovative teaching methods in enhancing student engagement and interest, which in turn helps lower dropout rates and boost academic performance. By implementing these strategies, students are more motivated to continue their studies, ultimately leading to the successful completion of their academic training.

According to Hertz and Chinn, an alternative pedagogical approach has been to reuse exam questions for multiple exams, claiming minimal impact on the overall scores [27]. In this regard, there was a study conducted by O'Neil in 2000, in which the impact of repeating questions on consecutive examinations was observed [28]. Results demonstrated that implementing the same questions did not factor into the overall scores [28]. In 2006, Jones *et al*. incorporated a more traditional approach regarding exams questions. In their study, exam questions were posed almost identical as prior exams, but with similar content to reduce the impact of previous material [29].

However, there has been extensive studies that focus on the need to control exam questions to avoid higher test scores and honor code violations [30], [31], [32]. According to a study conducted by DeChamplain *et al*. with a cohort of medical students, it was concluded that providing access to test material in advanced increased test scores.

In educational research, it has also been shown that providing step-by-step solutions for homework problems enhances student learning, particularly in STEM disciplines where problem-solving plays a crucial role. Previous studies have demonstrated that structured, guided problem-solving interventions can help students better understand complex concepts, reduce cognitive overload, and improve problem-solving abilities [33]. These interventions, which break down complex tasks into manageable steps, allow students to engage more deeply with the material and reinforce their learning.

II. PURPOSE OF RESEARCH

Objective of Study

This study sought to address some of these academic challenges in the context of a Rigid Body Dynamics course taught at a Hispanic-serving institution (HSI), during the Spring 2023 semester. Given the rigorous nature of the course, the authors implemented an alternative pedagogical strategy: 1) providing step-by-step solutions for each homework assignment concurrently with the assignments themselves; and 2) students were instructed that a homework problem, or a lecture notes problem(s), would be incorporated on each of the four semester in-class exams.

Similar to the approach incorporated by Hertz and Chinn, the focus of this study was to reuse homework questions and lecture problems on the exam to enhance students' comprehension of the material, promote academic success, increase passing rates (~70%) from previous semesters, and mitigate the temptation to violate academic integrity by engaging in dishonest practices. Further, exam problems identical to the homework or lecture notes would be evaluated individually to determine whether students understood homework solutions thoroughly. In this study, the cohort of students were not informed exam scores would be compared to previous semesters, in which homework solutions were not provided simultaneously with assignments.

The objective of this study further aligns with the academic challenge of the institution, particularly with retention rates. Based on the retention rates from Texas Public Universities, The University of Texas Rio Grande Valley (UTRGV) has an average freshman retention rate of 75% (Table 1) [26]. This data is relatively low compared to institutions across the state of Texas such as The University of Texas (95%), UT Dallas (88%), and the University of Houston (85%) but higher than many other institutions in the state. Not only are freshman retention rates affected at UTRGV, but also the retention rates of first year (full-time) students in the College of Engineering and Computer Science have been at an average of 60% between the Fall of 2015 and Fall 2019 (Table 2) [26]. According to the data, Retention rates of incoming students, for instance, declined to 53.3% in the Fall 2020, while retention rates within the institution similarly plunged to 60.9%.

Table 1. Texas Public Universities Freshman Retention Rates. Freshman entering in Fall 2022 through Fall 2024 (usnews.com/best-colleges/rankings) [26]

Texas Public University	Average Freshman Retention Rate
UT Austin	95%
Texas A&M University	95%
UT Dallas	87%
Texas Tech University	86%
University of Houston	85%
University of North Texas	80%
Texas State University	80%
Texas Woman's University	76%
UT Rio Grande Valley	75%
Sam Houston State University	75%
UT El Paso	75%
UT San Antonio	73%
UT Arlington	72%
Texas A&M Kingsville	68%
Texas A&M Commerce	66%
UT Tyler	64%
Texas A&M Corpus Christy	58%
Texas Southern University	54%

Table 2. UTRGV College of Engineering and Computer Science First Year Full Time Freshman 1st Year Retention Rate [26]

Cohort	Retention Within College	Retention Within University
Fall 2018	62.3%	78.2%
Fall 2019	66.6%	77.0%
Fall 2020	64.7%	74.9%
Fall 2021	69.4%	78.5%
Fall 2022	67.2%	79.0%
Fall 2023	53.3%	60.9%

An additional concern of the institution is passing rates in introductory engineering courses (Table 3). For instance, CIVE 1101 had passing rates in the Spring 2019 and Spring 2020 of 78.9% and 91.9%, respectively. However, the academic year surrounding COVID-19, passing rates fell significantly to 69.9% in the Fall semester and 63.1% in the Spring semester [26].

Table 3. Passing Rates in Intro to Engineering and Computer Science Courses [26]

Semester Course	Spring 2019	Fall 2019	Spring 2020	Fall 2020	Spring 2021
CIVE 1101 - Introduction to Civil Engineering	78.9% (n=83)	84.4% (n=122)	91.9% (n=74)	69.9% (n=156)	63.1% (n=84)
CMPE 1101 – Introduction to Computer Engineering	68.8% (n=32)	78.2% (n=110)	48.2% (n=54)	64.2% (n=95)	75.0% (n=48)
CSCI 1101-Introduction to Computer Science	62.8% (n=94)	75.8% (n=244)	70.2% (n=151)	78.0% (n=282)	67.6% (n=148)
ELEE 1101 – Introduction to Electrical Engineering	72.2% (n=36)	70.4% (n=81)	63.3% (n=49)	75.0% (n=88)	39.2% (n=51)
MANE 1101 – Introduction to Manufacturing Engineering	71.4% (n=21)		90% (n=20)	68.0% (n=25)	86.7% (n=15)
MECE 1101 – Introduction to Mechanical Engineering	67.4% (n=95)	75.2% (n=206)	70.6% (n=85)	69.3% (n=215)	57.9% (n=76)

III. METHODS AND ANALYSIS

This study was conducted to investigate the impact of reusing homework and lecture problems on exams in a Rigid Body Dynamics course. The assessment was conducted at a Hispanic-serving institution (HSI) during the Spring 2023 semester. The research sought to determine the effects of this pedagogical strategy on student comprehension, success rates, and adherence to academic integrity. A quasi-experimental design was used to compare the academic performance of students who were provided with concurrent step-by-step homework solutions (Spring 2023) to those from previous semesters (Spring 2022 and Fall 2022) who were not provided with such resources. The primary metric for evaluation was the average exam performance across four key assessments: Exam 1, Exam 2, Exam 3, and Final Exam.

Participants and Data Collection

The study involved undergraduate students enrolled in two sections of the Rigid Body Dynamics course over three consecutive semesters: Spring 2022, Fall 2022, and Spring 2023. The course is a core component of the engineering curriculum and is known for its rigorous content. The study examined the scores of twenty-four students in the Spring 2023 semester. In terms of the number of homework assignments given throughout the semester, a total of eight were given with the corresponding solution. Data on student performance were collected from the four major exams administered each semester, each consisting of four or five total questions. Exam scores were recorded as a percentage and used as the primary measure of student learning and success. The exam content and difficulty level were consistent across the three semesters to ensure comparability. The average exam scores from the Spring 2023 cohort were compared to those from Spring 2022 and Fall 2022 to identify trends and assess the impact of the intervention. Averages for Exam 1, Exam 2, Exam 3, and the Final Exam were calculated and analyzed using descriptive statistics to evaluate differences between cohorts.

Limitations

The study acknowledges several limitations that may have influenced the findings. Variability in student demographics and prior academic preparation across semesters could have impacted performance outcomes, as differences in background knowledge and readiness may vary between cohorts. Additionally, potential differences in instructional delivery or other external factors, such as changes in teaching methods or unforeseen circumstances, may have affected student learning and exam performance. Finally, the study's limited generalizability, due to its focus on a single course and a single institution, restricts the applicability of the results to broader contexts or diverse academic settings.

IV. RESULTS & DISSCUSSION

Results for Spring 2022 and Fall 2022 Cohorts

The average exam scores for the cohort of students from the Spring 2022 (43 total students) and Fall 2022 (38 total students) are recorded in Table 4 and Table 5, respectively. These students who completed the Rigid Body Dynamics class were not provided with homework solutions simultaneously with the assignment.

Table 4: Spring 2022 Exam Average Data

Exam 1	Exam 2	Exam 3	Final Exam	Pass Rate (%)
Avg. 81	Avg. 69	Avg. 73	Avg. 74	79

Table 5: Fall 2022 Exam Average Data

Exam 1	Exam 2	Exam 3	Final Exam	Pass Rate (%)
Avg. 71.6	Avg. 70.78	Avg. 61.5	Avg. 62.05	76.3

Results indicate that average exam scores for the Spring 2022 semester (solutions not provided) included: 81, 69, 73, and 74 out of 100 total points, respectively; and the averages for the Fall 2022 semester (solutions not provided) included: 71.6, 70.78, 61.5, and 62.05 out of 100 total points, respectively. Further, 79% of the cohort who completed the course in the Spring 2022 semester passed the course with a letter grade of C or better, while 76.3% of the cohort who completed the course in the Fall 2022 semester passed the course with a letter grade of C or better.

Results for Spring 2023 Cohort

The average exam scores for the cohort of students [Spring 2023] who received homework solutions simultaneously with their assignments are illustrated subsequently. Results indicate, in Table 6, that the average for Exam 1 was 53.3 out of 100 total points.

Table 6: Spring 2023 Exam 1 Data

Exam 1			
Avg.	Total Problems	Points/Problem	HW Prob. on Exam
53.3	4	25	1

For Exam 1, there was one problem identical to the homework set, while the other three problems were related to the homework assigned during the semester. According to the results in Table 7, only 2 students out of the 24 in the class, earned the full 25 points for the homework problem assigned during the exam, 8 of those students earned more than half of the points, 13 students earned less than half of the points, and 1 student did not earn any credit at all. These results indicate that more than 90% of the student population did not fully study, or understand, the homework solutions for the exam, though they had already completed their homework assignments with such solution sets.

Table 7: Analyzing HW Problem on Exam 1 – Spring 2023

Full 25 points	**12.5 points >**	**< 12.5 points**	**No points**
2 students	8 students	13 students	1 student

For Exam 2, results indicate that the average was 59.1 out of 100 total points (Table 8). On this exam, there was one problem identical to the homework set, and another identical to the lecture problems. Results indicate on Table 9 that only 6 students out of the entire class earned the full credit for the homework problem, 11 of those students earned more than half of the points, 6 earned less than half of the points, and only one student did not earn points. From these results, it is observed that there was an increase in students who received full credit, or at least more than half of the points, compared to Exam 1. It seemed several students were able to understand the importance of having the homework solutions, however, 75% of the population could not complete the entire problem correctly.

Table 8: Spring 2023 Exam 2 Data

Exam 2				
Avg.	Total Problems	Points/Problem	HW on Exam	Lect. Prob. on Exam
59.1	5	20	1	2

Table 9: Analyzing HW Problem on Exam 2 – Spring 2023

Full 20 points	**10 points >**	**< 10 points**	**No points**
6 students	11 students	6 students	1 student

For Exam 3, furthermore, results indicate that the average was 57.5 out of 100 total points (Table 10), just slightly lower than Exam 2. On this particular exam, all of the problems were identical to the lecture problems. Results indicate on Table 11 that less than 25% of the population received full credit for the corresponding problems. However, more than 60% of the students received more than half of the points for each of the four problems.

Table 10: Spring 2023 Exam 3 Data

Exam 3			
Avg.	Total Problems	Points/Problem	Lect. Prob. on Exam
57.5	4	25	4

Table 11: Analyzing Lecture Problems on Exam 3 – Spring 2023

	Full 25 points	**12.5 points >**	**< 12.5 points**	**No points**
P.1	0 students	15 students	8 students	1 student
P.2	2 students	15 students	6 students	1 student
P.3	6 students	13 students	3 students	2 students
P.4	4 students	14 students	5 students	1 student

For the final exam, the average was a 67.1 out of 100 total points, which turned out better than the previous three exams, but nonetheless, below the passing standard (Table 12). However, results indicated that students continue to struggle to earn full credit on the problem assigned directly from the homework set (Table 13).

Table 12: Spring 2023 Final Exam Data

Final Exam			
Avg.	Total Problems	Points/Problem	HW Prob. on Exam
67.1	4	25	1

Table 13: Analyzing HW Problem on Final Exam – Spring 2023

Full 25 points	**12.5 points >**	**< 12.5 points**	**No points**
1 student	17 students	3 students	3 students

From the data of the three cohorts, it is observed that the average for exam 1, exam 2, exam 3, and the final exam during the Spring 2023 semester (solutions provided) included: 57.1, 59.6, 55, and 55.2 respectively; while the averages for Spring 2022 semester (solutions not provided) included: 81, 69, 73, and 74 respectively; and the averages for the Fall 2022 semester (solutions not provided) included: 71.6, 70.78, 61.5, and 62.05 respectively (Table 14).

Table 14: Analysis between Semesters: Average and Passing Rates

	Spring 2022	**Fall 2022**	**Spring 2023**
Exam 1: Avg	81	71.6	53.3
Exam 2: Avg	69	70.78	59.1
Exam 3: Avg	73	61.5	57.5
Final Exam: Avg	74	62.05	67.1
Pass Rate %	79%	76.3%	58.3%

Unexpected results suggest that when the step-by-step homework solutions (Spring 2023) were provided, even the passing rates were affected. There was a 79% and 76.3% passing rate for the Spring 2022 and for the Fall 2022 semesters, respectively, while the data suggests a decline in passing rates of 58.3% in the Spring 2023 semester. The authors hypothesize that 1) providing the solutions concurrently with the homework assignment may be harmful to the overall student success in engineering education, 2) students are not allotting time to understand the step-by-step homework solutions, 3) students are memorizing solutions rather than understanding, and 4) violating the honor code is not the best option for success. However, further investigation is needed to validate these hypotheses. In particular, student interviews or surveys would help clarify whether students are not engaging with the solutions as intended, and whether there is evidence of academic dishonesty, such as sharing or copying solutions. To better understand the significant differences observed in the passing rates and exam scores, a t-test will be conducted as part of

future work to compare the means between the Spring 2023 semester, when step-by-step solutions were provided, and the Spring 2022 and Fall 2022 semesters. This statistical analysis will help determine whether the differences in performance are statistically significant and provide further insight into the impact of providing solutions concurrently with homework assignments.

V. CONCLUSION

This study was conducted to examine the impact of reusing homework and lecture problems on exams in a Rigid Body Dynamics course. Students were provided step-by-step homework solutions for each assignment. The objective was to determine the effects of this pedagogical strategy on student comprehension, success rates, and adherence to academic integrity. In this regard, the primary metric for evaluation was the average exam performance across four key assessments: Exam 1, Exam 2, Exam 3, and Final Exam.

However, the outcome was unexpected. The exam averages during the Spring 2023 semester, when solutions were provided, were significantly lower compared to previous semesters when solutions were not shared ahead of time. There was a 79% and 76.3% passing rate for the Spring 2022 and for the Fall 2022 semesters, respectively, while the data suggests a decline in passing rates of 58.3% in the Spring 2023 semester. These findings challenge the assumption that providing solutions would lead to improved learning outcomes and highlight the need for further investigation into the pedagogical practices that best support student success in engineering education.

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