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Assessing the Efficacy of a Pedagogy in an Online Mechanics of Materials Course with EFL Students

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Abstract

English as a foreign language (EFL) students encounter a diverse set of learning challenges due to inherent cultural barriers, like English language communication and misconstrued behaviors from non-verbal communication. Engineering courses involve complex subject matter with nuanced concepts and are commonly structured with prerequisite courses. This requires EFL students to have a proficient level of academic preparation and foundational knowledge. All these factors compound the learning challenge that EFL students must overcome to persist and complete an online engineering course that is taught in English.

The present paper builds on a previous work where a pedagogy with a lean instructional methodology was developed for EFL students in an online Mechanics of Materials course (82% asynchronous and 18% synchronous). The lean methodology relied on reduced question sets for homework, a guided mapping of key technical terms, and alternative text explanations for problem figures. These instructional materials were designed to decrease the student's cognitive load and establish a toolkit to support their learning. The results of the initial deployment showed an increase in student engagement. However, it was inconclusive whether the homework completion grade was affected by the pedagogy. The results also showed that the homework had a weak positive correlation with exam performance.

The present paper further aims to assess the efficacy of the pedagogy by examining student engagement and student performance across multiple cohorts of the course. Learning management system tools, like chat and polling, were previously shown to be effective qualitative methods for overcoming the passive learning behavior exhibited by EFL students. Thus, a comparison by cohort and in aggregate were performed for the following: student participation at each synchronous Q&A session using the chat feature, student polling throughout the semester (before, during, after), homework grade data, and exam grade data. Student engagement increased 17% in Cohort 2022 compared to 2021, which validated the support for using chat and polling. Students reported in polling that they needed the lean methodology more as the semester progressed even though homework performance wasn't positively impacted. It was also found that students relied on the lean methodology to complete the midterm and final exams. An analysis of both HW 1 and HW 2 revealed a statistically significant performance benefit in homework assignments by using the lean methodology with a moderate to large effect.

EFL students, engineering, pedagogy, efficacy

Introduction

An English as a foreign language (EFL) student is a student who learns in a country where English is not the native language. It is common for an EFL student to experience significant learning challenges because of their weak English communication skills. Other cultural factors, like identity, teacher-student hierarchy, and individualism may also contribute to student success and student persistence [1]-[2].

The Mechanics of Materials course in the present study is taught 100% online and in English, which comprises lectures, homework assignments, and examinations. While the Test of English as a Foreign Language (TOEFL) is a commonly used standardized test, student scores were not made available since English-speaking instructors are not considered full-time employees of the university in China. The online course delivery model is a mixture between asynchronous (82%) and synchronous (18%) modes. The online, asynchronous format can hinder EFL students from participating or engaging in class since EFL students are traditionally passive learners and do not typically learn on their own [1]-[3]. The EFL students in the present study enter the Mechanics of Materials course with the additional challenge of having undeveloped skills and poor knowledge in Statics or Physics, despite being exposed to those subjects as pre-requisites for Mechanics of Materials. Thus, the barriers to student learning faced by EFL students in Mechanics of Materials and online courses in general must be addressed to ensure that their academic success does not decrease [4]-[6].

In [7], a pedagogy with a lean instructional methodology was developed to overcome these learning barriers. The lean methodology was composed of reduced question sets homework assignments, a guided mapping of key technical terms, and alternative text explanations for problem figures. Some validity exists in the literature for adapting an instructional methodology that simplifies the complex, technical terms in engineering courses without sacrificing the learning benefit to EFL students. Lackey et al. [8] assessed the efficacy of a true and false question test versus a traditional problem-solving or essay test, which showed improved cognitive skills and an overall learning benefit. Another study showed a high correlation between the Test of English as a Foreign Language (TOEFL) score and student performance among international civil engineering students [9]. Thus, the reduced question sets in the lean methodology aimed to decrease cognitive load and scaffold the concepts asked in a problem. This segmented structure supported EFL students as they learned new topics that built on prerequisite material.

Moreover, the key terms and figure explanations provided students with a simplified description of the problem that could meet all student's level of English proficiency. This was key since the authors in [3] note that cultural background may play a significant role in the language learning strategies that students prefer and apply in class [3], [10]. Leung et al. performed two studies on the differences between university students in Hong Kong, which are considered to have a Western student culture, versus mainland China, which are considered to have a traditional Eastern student culture [2], [11]. The results showed that mainland students partially relied on student-centered learning approaches that use metacognitive skills even though mainland students typically adopt a teacher-centered approach that use deep learning skills [2]. Thus, the EFL students in the present paper fall under the mainland China student type. The lean

instructional methodology was developed by considering the specific conditions of the students in the course to help them achieve an improved level of academic success and yield the deep learning benefits observed in [2].

In the section that follows, a brief background of the lean instructional methodology and methods used are presented. The results will follow and comprise a discussion about student engagement, homework performance, and exam performance. These results focus primarily on the most recent implementation of the pedagogy (Cohort 2022), but includes comparisons to Cohort 2021 to highlight specific year-over-year findings. The paper ends with conclusions drawn from the multiple deployment of the instructional pedagogy and list future work.

Methods

A brief background of the lean instructional methodology that was developed in a previous work [7] is presented here to provide context. The recent cohort (Cohort 2022) of the Mechanics of Materials course was comprised of 95 EFL students attending a Chemical Engineering university in a small Chinese province. All course content (lectures, notes, and assignments) were delivered in English. The semester was 9 weeks with a mixture of asynchronous lectures (82% of lectures) that were recorded and played for students in class by a teaching assistant, and synchronous lectures (18% of lectures) that were live Q&A sessions and conducted by the instructor.

The investigation in [7] found that polling in classes with EFL students yielded positive results for student engagement since most students are too shy or unwilling to verbally communicate their questions. So, it was key to use polling again to determine if the impact on student engagement would remain positive among different engagement activities, such as live Q&A sessions and polling about the lean methodology. The latter formed the basis for the first research question:

- How much do students rely on the lean instructional methodology to complete the homework assignments and exams?

For both homework and exams, student performance grades are compared with polling results to address the question. The chat and polling features in DingTalk, a learning management system [12], were used to encourage students to write in their questions. DingTalk also has other capabilities, like file sharing and web conferencing, for students to submit their assignments and to attend the live Q&A sessions.

Figure 1 shows a couple of examples of the polling feature, which used a 5-point Likert scale for each of the questions asked. A summary of the class responses are shown in Fig. 1 for an instructor, but students could not see what how other students were responding. The polling was conducted four times throughout the semester. The first poll was conducted at the start of the semester to understand student perceptions about their English communication skills (overall, verbal, written, reading). This poll also included questions about their prerequisite knowledge in Statics or Physics, which were subjects that they completed prior to Mechanics of Materials. Three additional polls were conducted throughout the semester to provide qualitative context to the quantitative results with the goal of assessing the efficacy of the instructional pedagogy.

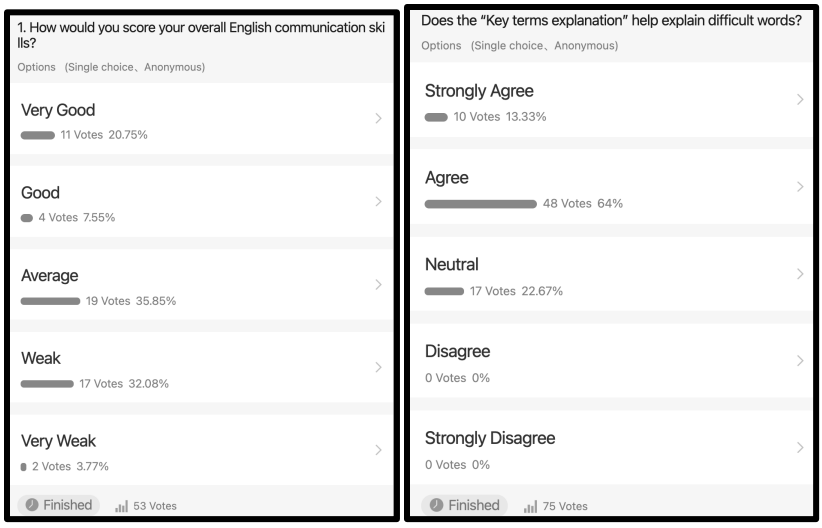

Figure 1. Examples of two poll questions showing the possible responses.

Homework assignments and exams used a three-part teaching methodology comprising reduced question sets, a guided word mapping, and figure explanations. The guided word mapping underlines key technical terms and lists the terms in a box. The box is positioned below the problem statement and each term is given a simple synonym or short explanation. The figure explanations are written in the form of alternative text and presented as figure captions. The reduced question sets scaffold the problem by segmenting a question into sub-parts and leverage the guided word mapping and figure explanations. The design of homework assignments and exams were intended to make it easier for students to process the problem statement, understand the questions being asked, and reduce cognitive load. Thus, the second research question was:

- What is the level of improvement in student performance by using the lean instructional methodology in homework assignments and exams?

To address this question, homework data from Cohort 2021 served as the control and is compared to the data in Cohort 2022. Since no control data existed for exams, student performance was compared on a year-over-year basis.

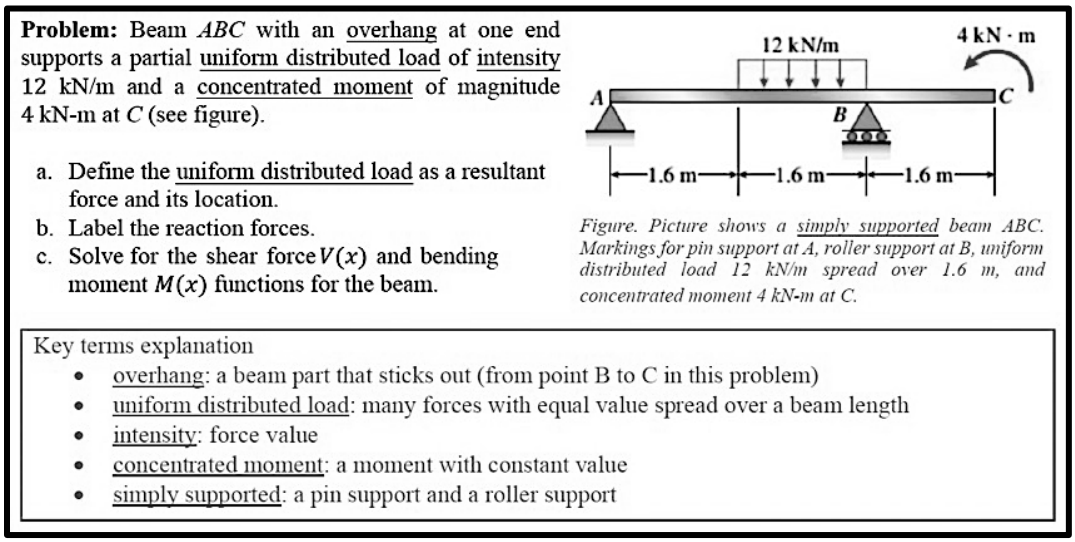

Figure 2. Example of a homework question showing the elements of the lean methodology.

Results and discussion

The results of the student engagement activities, homework completion, homework performance, and exam performance are discussed next.

Student engagement

It is known that student engagement is low, not only when EFL students are enrolled in an online course, but also among students in Mechanics of Materials at the university. However, it was shown in [7] that using polling in an online class with EFL students has a positive impact on student engagement. Table 1 lists the Poll 1 questions that students were asked to answer at the start of the semester for Cohort 2022. Poll 1 focused on establishing student perceptions upon entering Mechanics of Materials as it relates to both English communication skills and prerequisite knowledge in the subject area.

Table 1. Poll 1 questions to establish student perceptions with English communication skills and prerequisite knowledge.

Poll	Questions
Poll 1	Q1. How would you score your overall English communication skills? Q2. How would you score your English speaking skills? Q3. How would you score your English writing skills? Q4. How would you score your English reading skills? Q5. How would you score your Engineering Statics or Physics knowledge? Scale: Very Weak, Weak, Average, Good, Very Good

Only 55 out of 95 students responded to Poll 1 (58% participation), which shows the initial hesitation among EFL students to engage in the class. 72% of students rated themselves as being average or below average (i.e., very weak or weak) in their overall English communication skills (Q1). In terms of speaking, writing, and reading skills (Q2-Q4), 78-81% of students rated themselves as being average or below average. This means that roughly three-quarters of the students that participated in the poll entered the course with a low perception of their ability to communicate in English and engage in class. Also, 76% of students rated their knowledge in Statics or Physics as average or below average, showing a lack of transfer knowledge after taking those courses as prerequisites to Mechanics of Materials. The results of Poll 1 confirm that both English communication skills and prerequisite knowledge are average at best, and both are significant challenges for an EFL student enrolled in an online Mechanics of Materials course.

Chat and polling features were both used to overcome the barriers to participation and improve student engagement. Figure 3 below depicts the number of students that typed questions or comments in the chat forum at each of the three live Q&A sessions, marked as S1, S2, and S3. The four polls that were conducted throughout the semester to document student feedback on the lean instructional methodology are marked as P1, P2, P3, and P4.

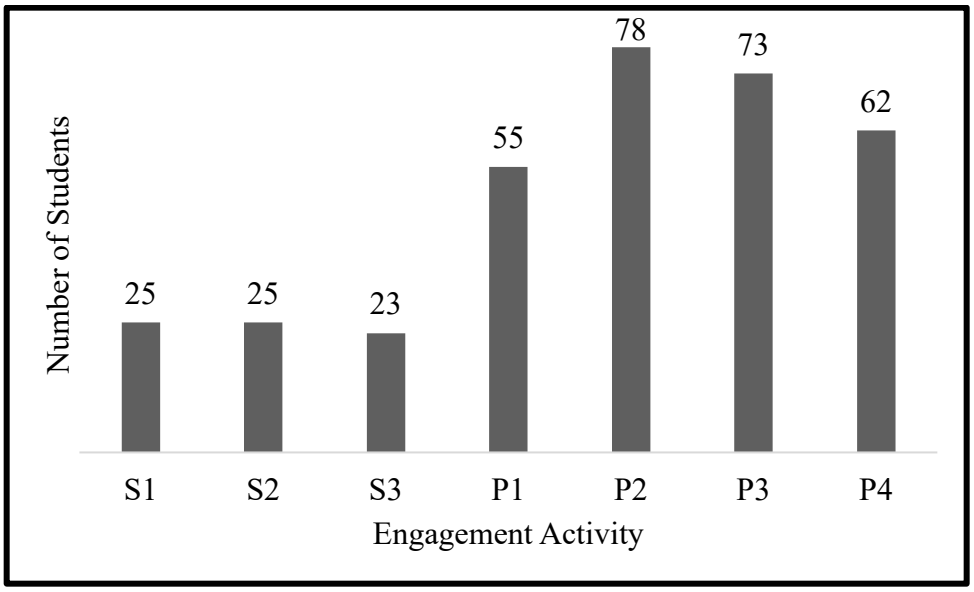

Figure 3. Student engagement at live Q&A sessions using chat and polling features, where S = (live Q&A sessions) and P = (student polling events).

The results from using the chat forum were positive and consistent. A total of 73 questions and comments were typed across S1-S3 with two instances of 25 occurring as the high. By comparison, Cohort 2021 had a total of 8 questions and comments with 4 as the high [7]; a significant improvement on the order of nine times. The results of the polling were also positive. The responses peaked at 78 students (82% participation) in Poll 2, followed by a steady decrease down to 62 students (65% participation) in Poll 4. No obvious trend emerges when multiple polls are used between Cohort 2022 and Cohort 2021. However, the participation rate improved in Cohort 2022 ranging between 58-82% compared to 30-65% in 2021, where only three polls were used. The specific details of the questions asked in Polls 2-4 and the response results are discussed in the section that follows.

Homework completion

The homework completion grade was tracked to evaluate how well students were responding to the lean methodology implemented in the homework assignments. Homework completion was defined as the completeness in terms of hand work that was submitted for a given homework assignment. The homework completion results for Cohort 2022 varied across the 7 homework assignments as shown in Figure 4 and is discussed further in the next section.

Table 2 lists the questions in Polls 2-4, where Poll 2 was asked in week 3, Poll 3 in week 6, and Poll 4 in week 9 of the semester. Polls 2-4 (Q1-Q2 and Q4-Q5) were used to extract more information from the homework completion grade by querying students about the specific components of the lean methodology.

Table 2. Poll questions to evaluate the efficacy of pedagogy.

Poll	Questions
Polls 2-4	Q1. Does the "Key terms explanation" help explain difficult words? Q2. Does the "Key terms explanation" make difficult words easy to understand? Q3. The "Key terms explanation" was needed to complete the homework. Q4. Does the "figure explanation" help explain the picture? Q5. Does the "figure explanation" make the picture easy to understand? Q6. The "figure explanation" was needed to complete the homework. Scale: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

When asked if the explanation of key terms helped (Q1), the number of neutral and strongly agree responses showed a steady decrease, while slightly more students agree that the explanations helped in HW 1 to HW 7. The strongly disagree and disagree responses remained constant. However, there were also fewer responses between Poll 2 and Poll 4 (13 few responses), which may account for the small decrease rather increase in Poll 4 for the agree response. Q2 served to clarify a student's interpretation of Q1. Since the results of Q2 were similar in trend to Q1, it confirms that the amount of agreement increased slightly through the course of the semester. The results about whether the explanations of the figures helped (Q3-Q4) also showed the same trends and conclusions as in Q1 and Q2. Thus, the lean methodology of having key terms and figure explanations in homework assignments were useful to students.

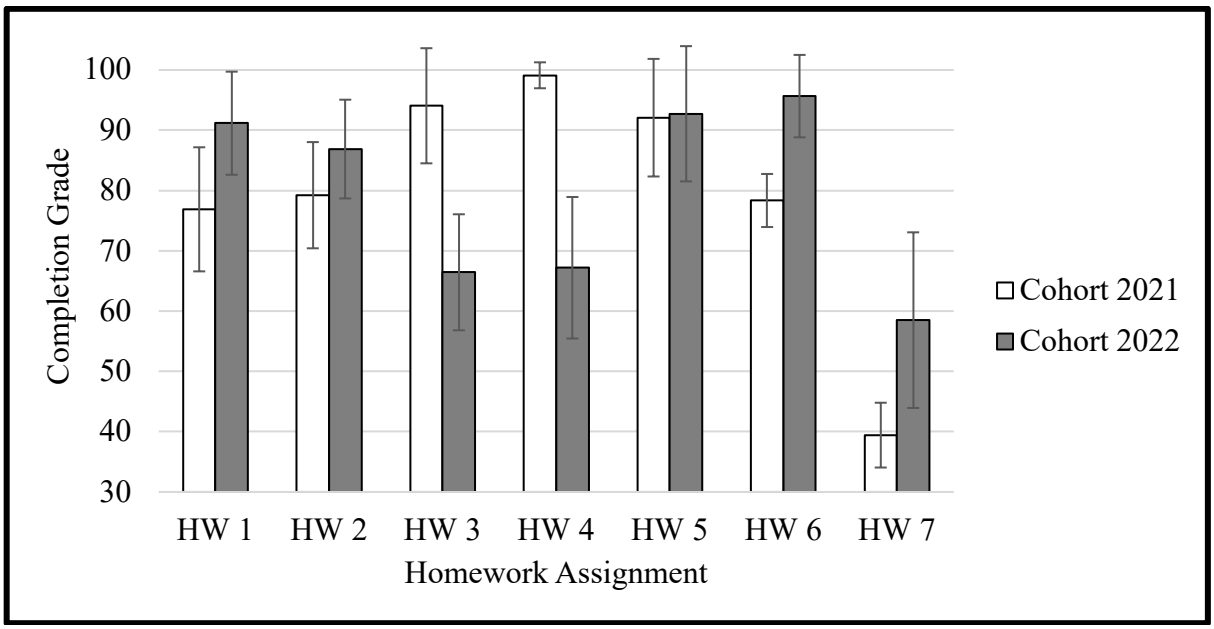

Figure 4. Comparison of homework completion between cohort 2021 and 2022.

From an efficacy perspective, it was important to assess whether students rely on the lean methodology less, more, or the same in HW 1 to HW 7 (Q3 and Q6). In other words, is there a correlation between student usage of the key terms and figure explanations and homework performance for Cohort 2022? The results show that students relied on the key terms explanations (Q3) slightly more throughout the semester, whereas it remained the same for the

figure explanations (Q6). It was found that students *needed* the key terms and figure explanations the most after HW 3 and HW 4 based on the agree and strongly agree responses in Poll 3, which corresponded to the lowest homework averages scored (see Fig. 4, Cohort 2022). Similar trends for HW 1 and HW 2 using Poll 2 and HW 5 to HW 7 using Poll 4 were observed. While the student responses showed an earnest need to use the lean methodology, it didn't always translate to an improvement in homework performance. In fact, when compared to Cohort 2021, the performance was worse for HW 3 and HW 4 in Cohort 2022.

Homework performance

Figure 4 compares the homework performance between Cohort 2021 and Cohort 2022 across all seven homework assignments. Overall, students in Cohort 2022 performed better compared to students in Cohort 2021 by about 11.8 points on average. The exception was in HW 3 and HW 4 as discussed in the previous section, where Cohort 2022 performed significantly worse than Cohort 2021; 29.8 points on average. The midterm was ruled out as a contributing factor since the exam was scheduled much later than the two homework deadlines. More investigation is needed since HW 3 and HW 4 were the highest performing assignments for Cohort 2021.

A key analysis in assessing the efficacy of the lean methodology is the student performance in HW 1 and HW 2 between the two cohorts. Cohort 2021 completed HW 1 and HW 2 without the lean methodology and is used as the control group, whereas Cohort 2022 did use the lean methodology. A two-tailed Z-test was performed for each homework using the sample means. For HW 1, the sample mean was 76.9 with a standard deviation of 20.7 for Cohort 2021 and the sample mean was 91.2 with a standard deviation of 17.1 for Cohort 2022. This comparison yielded a p-value equal to 3.04e-07 ($p < 0.05$), a statistically significant result. The effect size is 0.84, which shows a large effect. For HW 2, the sample mean was 79.2 with a standard deviation of 17.6 for Cohort 2021 and the sample mean was 86.9 with a standard deviation of 16.4 for Cohort 2022. This comparison yielded a p-value equal to 0.002 ($p < 0.05$), which is also a statistically significant result. The effect was moderate since the effect size is 0.47. The results of both analyses show the statistical significance of the lean methodology when implemented in homework assignments. The moderate to large effect further supports the impact on student performance.

Exam performance

The lean methodology was also implemented in both the midterm and final exams. It was much more difficult to uncover the impact unless another metric, like homework average, is used to correlate positive performance on the midterm and final exams, as shown in Figure 5. All data was sorted in ascending order relative to the homework average (7 homework assignments).

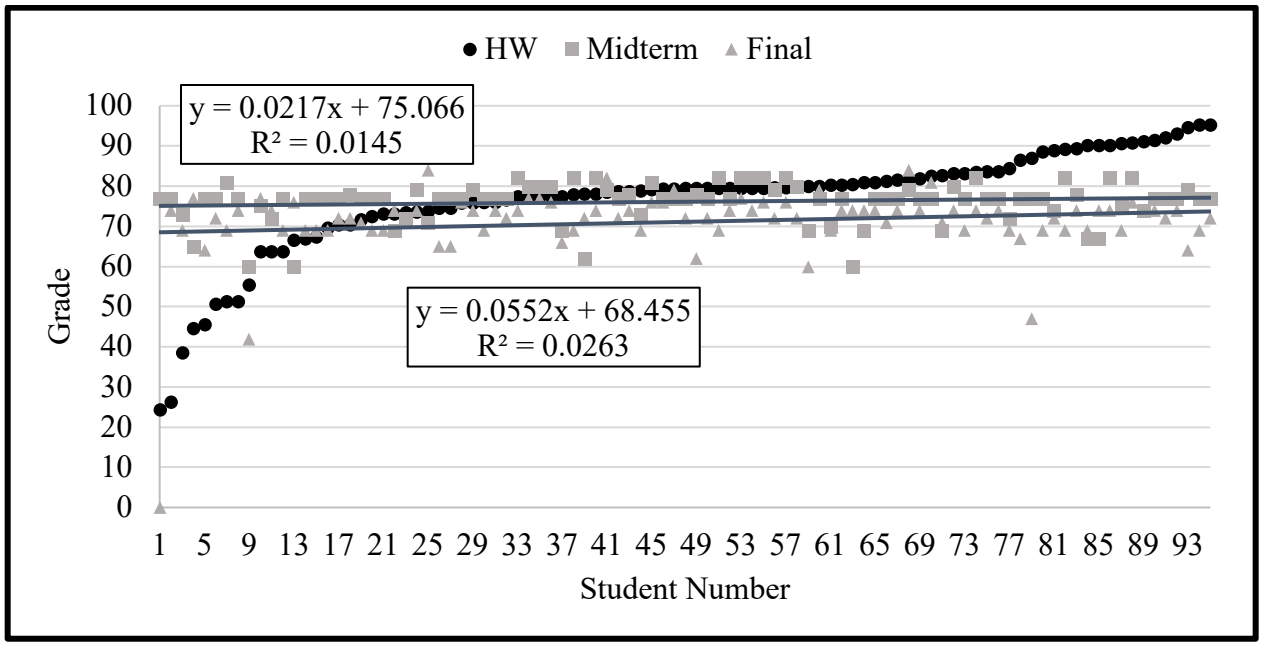

Figure 5. Midterm and final exam scores for each student relative to homework completion. The trendlines for the midterm and final exams are shown relative to homework completion.

The analysis conducted for Cohort 2021 showed that the homework average had a weak positive correlation with exam performance. Unlike in 2021, the results from Cohort 2022 were less clear as to whether the lean methodology positively affected exam grades. Midterm scores remained constant relative to homework average (i.e., no correlation) with a midterm average of 76.1 and median at 77. The final exam scores showed a weak positive correlation with homework average, but with a final average of 71.1 and median at 72, which was lower than midterm scores. Despite an improvement in average midterm score from 66.6 to 76.1, the average final exam score decreased from 85.2 to 71.1 between Cohort 2021 and Cohort 2022.

Table 3 lists two additional questions that were included in Poll 4. These questions were similar to Q3 and Q6 in Polls 2-4 and aimed to understand how much students relied on the lean methodology to complete each exam. Students responded that they agree or strongly agree with needing the lean methodology; 83% for the midterm and 80% for the final exam. This result is consistent with the positive trend in need that was observed in Polls 3 and 4 for students needing the lean methodology in homework assignments.

Table 3. Additional questions included in Poll 4 to understand student reliance on lean methodology in exams.

Poll	Questions
Poll 4	Q7. The key terms and figure explanations were needed to complete the midterm exam? Q8. The key terms and figure explanations were needed to complete the final exam? Scale: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree

Conclusions

This paper assessed the efficacy of a pedagogy with a lean instructional methodology that implemented in an online Mechanics of Materials course with EFL students. The lean methodology comprised reduced question sets, a guided word mapping of key technical terms, and figure explanations. The results across two cohorts from 2021 and 2022 were considered. Student engagement was previously found to be positively impacted when a chat forum and polling are used for online courses with EFL students. The chat forum produced 9 times more questions and comments in Cohort 2022 compared to 2021. Also, the student participation rate in the 4 polls improved with 58-82% in Cohort 2022, whereas it was 30-65% in Cohort 2021, which was considered a significant level of participation in 2021. Thus, chat and polling do work to overcome the passive learning behaviors among EFL students and initial hesitancy to engage in online courses, as shown in Poll 1 results. It was also found that students earnestly need the lean methodology in homework assignments and both exams. This reliance did not necessarily equate to an improvement in homework performance, but students do recognize the lean methodology as a resource. More work is needed in this area to understand the results of Q3 and Q6 in Polls 2-4; perhaps, the lean methodology in homework assignments and exams can be made optionally available. HW 1 and HW 2 were compared between Cohort 2021 (no methodology implemented) and Cohort 2022 (methodology implemented). The results showed a statistically significant result from using the lean methodology in homework assignments with a moderate to large effect. The midterm scores had no positive correlation with homework performance and the final exam scores had only a weak positive correlation. A possible reason for these results is that students were expected to use a new methodology while also learning new concepts; the benefits of one component may have counteracted the other in the case of EFL students. Despite these findings, the lean instructional methodology appears to be the most useful when EFL students are practicing solving problems in homework versus when they are tested under time constraints.

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