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A simplified instructional methodology for a Mechanics of Materials course with EFL students

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Abstract

A simplified methodology was developed for teaching Mechanics of Materials to English as a foreign language (EFL) students. The methodology is built on reduced question sets for homework, a guided mapping of key technical terms, and alternative text explanations for problem figures. Foreign exchange student programs comprise a student population that struggle with weak English skills (both speaking and writing), cultural barriers (perception of teacher-student hierarchy and a vocal leader of the class), and self-identity (shyness and confidence to engage in class). In addition, foreign students entering a Mechanics of Materials course have poor foundational knowledge in subjects like Physics and/or Statics and encounter difficulties learning in a virtual course delivery model (82% asynchronous and 18% live Q&A sessions). The combination of these challenges exacts a tremendous obstacle to student learning, student retention, and student persistence.

The developed instructional approach uses reduced question sets for homework assignments, which aim to improve the lower-level questioning found in Bloom's Taxonomy and Costa's Levels of Thinking and reducing the higher-level questioning. This model helps to decrease the cognitive load that is placed on EFL students, while maintaining a suitable level of rigor so that students get the needed practice and application of new concepts. Mechanics of Materials and engineering subjects in general use complex terminology that is not easily understood by EFL students. The guided mapping of key technical terms provides students a list of simple synonyms and short explanations below problem statements. Similarly, problem figures are another obstacle for students, and they expressed the need for a description of the content being displayed in the figure. Thus, figure explanations in the form of alternative text were provided below the figures as captions, which also used the simplified terminology. These instructional methods equip students with a toolkit for reducing the challenges of taking an online course in English, so that they can focus on learning the course material.

The effectiveness of the developed instructional approach was assessed by measuring student participation at each live Q&A session, completeness of submitted homework (historically very low), student polling (before, during, after), and student performance (midterm and final exam grades). The results show increased levels of student engagement at the live Q&A sessions by using a chat forum and largely due to student polling. By using more tools, like polling, the results are promising for addressing passive learning behavior observed in EFL students. Student performance results showed a positive improvement between midterm and final exams (average increased from 66.5 to 85.2). These results were correlated with homework completion and observed to have a positive outcome in the course. The qualitative and quantitative student feedback was also very positive, which is encouraging that further deployments of the instructional methodology will support student learning for EFL students.

Introduction

Foreign exchange student programs are composed of English as a second language (ESL) and English as a foreign language (EFL) students. The classification ESL is reserved for students learning in a country where English is the dominant or official language, whereas EFL is reserved for students learning in a country where English is not the native language. The students in the Mechanics of Materials course for the present study are EFL students since they reside in a province on mainland China. The course lectures are completely online and conducted in English, including the course content (e.g., lecture notes, homework assignments, and exams).

ESL and EFL students encounter a diverse set of obstacles that affect student learning, student retention, and student persistence. Some factors contributing to these obstacles include, but are not limited to: weak verbal and written English skills, cultural barriers relating to individualism, self-identity, and teacher-student hierarchy [1-2]. The EFL students in the present study are also faced with the challenge of having undeveloped skills in pre-requisite courses. Mechanics of Materials is an engineering course comprising students that typically enter with a poor knowledge in the subjects of Physics and/or Statics. So, the need exists for simplifying the instructional methodology that eases students into the new topics that build on the pre-requisite material. A final challenge for the EFL students in the Mechanics of Materials course is the delivery model. The course is taught 100% online with mixed synchronous and asynchronous modalities. China is an Eastern civilization with cultural values that emphasize the individual and its students are traditionally passive learners with minimal learner autonomy [1]-[3]. So, it's highly likely that an EFL student may not or want to participate and engage in an online class. Unless proactive measures are taken by an instructor to mitigate or overcome learning challenges, academic success is observed to decrease in online courses [4]-[6].

The present work focused on understanding the tools available with language learning strategies (LLS) and their effectiveness. The goal was to consider ways for implementing LLS in engineering courses, which often involve complex, technical terms. LLS were originally classified into six groups: memory, cognitive, compensation, metacognition, affective, and social [7]. Even though the definitions for these classifications have evolved and received some criticism [8]-[9], they provide a framework for how the research has attempted to teach students with weak English skills. The use of specific LLS for students with a low English proficiency was studied by [3]. While the study showed that metacognitive and affective strategies correlated the best with English proficiency (i.e., metacognitive and affective strategies are the most effective learning strategies among students that are proficient in English), the authors mention that cultural background may also play a significant role in the LLS types that students prefer and apply in class.

Leung et al. [2], [10] investigated in two studies the differences between university students in Hong Kong (considered to have a Western student culture) and mainland China (traditional Eastern student culture). While Hong Kong students use an avoid-failure approach based on an achieving motivation and surface learning strategy, mainland students showed that they tend to adopt a deep learning approach most related to transferring and shaping teaching approaches (i.e., teacher-centered). The study findings revealed that learning approaches for mainland students do not entirely rely on the teaching approach used (student-centered vs. teacher-

centered), which challenges the traditional relationships between teaching approaches and learning approaches (surface and deep). The authors attribute the anomaly to an internal disposition by mainland students to use metacognitive skills in the learning process, so they don't fully depend on the teaching approach adopted by the instructor. The EFL students in the Mechanics of Materials course more closely align with the mainland student type in [2] since the EFL students reside in a small Chinese province that is unlike large metropolitan cities, such as Hong Kong or Beijing.

Thus, there is some validity in adapting an instructional methodology that simplifies the complex, technical terms in engineering courses without sacrificing the learning benefit to EFL students. Lackey et al. [11] assessed the efficacy of a true and false question test vs. a traditional problem-solving or essay test (i.e., non-true and false test). The authors concluded that a varied test item format helps improve the student use of cognitive skills and leads to an overall learning benefit. Another study of international engineering students investigated the relationship between Test of English as a Foreign Language (TOEFL) score and academic success [12]. While it was found that engineering students tend to be less dependent on English language proficiency, the authors state that this may not always be the case as evidenced by some engineering majors. For example, civil engineering students showed a high correlation between TOEFL score and student performance. So, if an instructional methodology for engineering courses can be approached intentionally on a case-by-case basis, then EFL students may experience an increase in academic success and yield the deep learning benefits observed by [2].

In the next section, the details of the instructional methods that form the foundation for the simplified methodology are presented. Then, the results from student responses and academic performance data are summarized and discussed. The paper ends by drawing conclusions about the initial implementation of the simplified methodology and suggestions for improvement in future work.

Methods

The Mechanics of Materials course was comprised of 91 EFL students attending a Chemical Engineering university in a small Chinese province. The course content was delivered in English over a 9-week semester. DingTalk served as the learning management system with features for file sharing, a chat forum, email, and web conferencing with drawing capability [13]. The lectures were a mixture of asynchronous (82%) and synchronous (18%) modalities. The asynchronous lectures consisted of recorded videos (38 sessions, each about 40 minutes), while the synchronous lectures offered a live question and answer, or Q&A, format (4 sessions, each about 80 minutes). One teaching assistant was assigned to the course and helped facilitate the in-person communication with students, setup the live Q&A sessions, and proctor exams. A total of seven homework assignments were assigned and two exams (midterm and final exam).

Homework assignments

Engineering courses, like Mechanics of Materials, generally use complex terminology that is not easily understood by EFL students. For example, terms such as *cantilevered* and *rivet* may create confusion at first. By simplifying complex terms, a student's understanding is increased, while

their cognitive load is decreased. A guided word mapping was developed by underlining key technical terms in a given problem statement and listing the terms in a box below the problem statement as shown in Fig. 1. Each term is provided with a simple synonym or short explanation.

Problem: Beam *ABC* with an overhang at one end supports a partial uniform distributed load of intensity 12 kN/m and a concentrated moment of magnitude 4 kN-m at *C* (see figure).

a. Define the uniform distributed load as a resultant force and its location.
b. Label the reaction forces.
c. Solve for the shear force $V(x)$ and bending moment $M(x)$ functions for the beam.

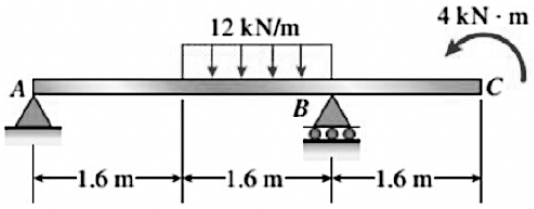

Figure. Picture shows a simply supported beam ABC. Markings for pin support at A, roller support at B, uniform distributed load 12 kN/m spread over 1.6 m, and concentrated moment 4 kN-m at C.

Key terms explanation

- overhang: a beam part that sticks out (from point B to C in this problem)
- uniform distributed load: many forces with equal value spread over a beam length
- intensity: force value
- concentrated moment: a moment with constant value
- simply supported: a pin support and a roller support

Figure 1. Example problem statement showing guided mapping of key technical terms.

Students also expressed their struggle with the content presented in problem figures. Thus, figure explanations in the form of alternative text were provided as figure captions (see Fig. 1). Alternative text fit well in the methodology since it is concise, so that it represents the content and function of the image [14]. When possible, the same word mapping used in the problem statement was incorporated into the figure explanations. The guided word mapping and figure explanations formed a cohesive description for problems in Mechanics of Materials and served as the foundation for the simplified methodology.

A third layer to the methodology was the implementation of reduced question sets. These question sets were aimed at leveraging the key terms and figure explanations to improve the lower-level questioning in Bloom's Taxonomy (remembering, understanding) and Costa's Levels of Thinking (input: gathering information), while reducing the higher-level questioning and thinking [15]-[16]. The latter part goes against the types of questions that might enhance deeper understanding and learning. But, if EFL students are struggling with mastery at the lower level, then there is an argument for adopting an approach that emphasizes the lower-level questioning and thinking. For example, questions that asked students to define, explain, identify, and label were predominant, while questions that asked students to apply, analyze, or process information were secondary (see Fig. 1).

This model aimed to further decrease the cognitive load that is placed on EFL students yet maintained a suitable level of rigor. The three instructional methods equipped students with a toolkit for reducing the challenges of completing homework, so that they could focus on learning the course material. As a result, one research question aimed to determine whether submission rate was affected by the instructional methods in the homework assignments.

Exams

The midterm and final exams were designed similar to the homework assignments. All three methods (guided word mapping, figure explanations, and reduced question sets) were employed. This unique design of the exams would make it easier for students to process the problem statement, easily understand the questions, and reduce any other obstacles due to language proficiency. The two exams were timed assessments (each 90 minutes), which is typically a struggle point for most students (not only EFL students). After the simplified methodology was implemented in homework but prior to the midterm exam, more students were submitting their homework assignments and completing more of the problems. So, another research question was to determine whether homework submission rate (graded based on completeness) translated to good performance on the midterm and final exams.

Student engagement

The level of student engagement was investigated by using the chat and polling features in a learning management system called DingTalk. The live Q&A lecture sessions were intended to give students the opportunity to ask the instructor questions directly. Since most of the students typically had their video cameras off and were too shy or unwilling to verbalize their questions, the chat feature helped them to write in their questions. In addition, the polling feature enabled the ability to create questions in order to assess the effectiveness of the simplified methodology. Thus, a few more research questions were important to answer:

- How was student engagement affected throughout the semester?
- What were the student attitudes about the instructional methods used in the homework assignments?
- What were the student attitudes about the instructional methods used in the midterm exam?

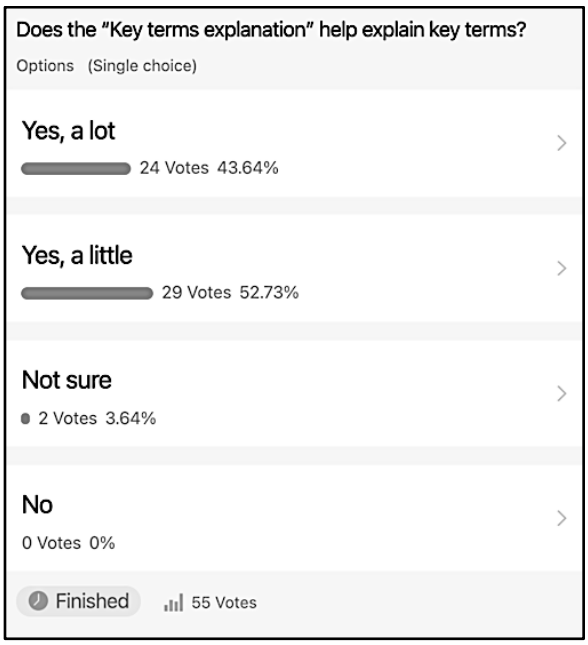

Figure 2. Example poll question.

Figure 2 shows an example of the poll questions asked, “Does the ‘Key terms explanation’ help explain key terms?”. Four response choices were given: Yes, a lot; Yes, a little; Not sure; No. These response choices were kept simple and remained the same for all other poll questions. The reasoning for this was to maintain consistency and to avoid any student confusion.

Results and discussion

The critical research questions mentioned in the previous section are listed here in the order they will be addressed. The goal of this work was to answer these questions to evaluate the effectiveness of the simplified instructional methodology and outline pathways for possible improvement.

- How was student engagement affected throughout the semester?
- What were the student attitudes about the instructional methods implemented in the homework assignments?
- How was homework submission rate affected by the instructional methods in the assignments?
- What were the student attitudes about the instructional methods implemented in the midterm exam?
- Did homework submission (graded based on completeness) translate to good performance on the midterm and final exams?

Student engagement in classes involving Chinese students is typically low due to passive learning and lack of responsiveness to the instructor [1]-[2]. However, the active use of the chat and polling features in the present work were aimed at increasing student engagement. Figure 3 depicts the number of students that explicitly submitted questions and comments in the chat forum at each of the four live Q&A sessions (indicated by S1, S2, S3, and S4). The results of the chat were inconclusive and showed no positive or negative trend in student engagement. A factor that likely played a role in the results was the low number of chat opportunities given to students by the number of live Q&A sessions. Perhaps, conducting live office hour sessions would be a possible solution. It should be noted that there were no instructor office hours since it was not required by the foreign exchange student program.

Three separate polls were conducted throughout the semester to document student feedback on the other teaching components (indicated by P1, P2, and P3 in Fig. 3). The initial polling was promising with 59 out of 91 students participating (64.8%). However, the participation rates dropped to 27 and 35 students (29.7% and 38.5%, respectively) in subsequent polls. The results from the chat forum and question polls showed that students initially found these features appealing. However, students quickly reverted to passive learning despite the encouragement from the instructor to continue using the chat forum and answer poll questions. Students responded less to the instructor as the semester progressed, indicating that student participation and engagement decreased. Regardless, there are some positive take-aways. For example, a few students showed the confidence to write in their questions and comments in the chat forum. Anecdotally, this was a behavior rarely observed among EFL students by the teaching assistant. Also, student participation in the polling ranged from 29.7% to 64.8%, which means that using poll questions is a good tool for improving student engagement and should be used more in courses with EFL students.

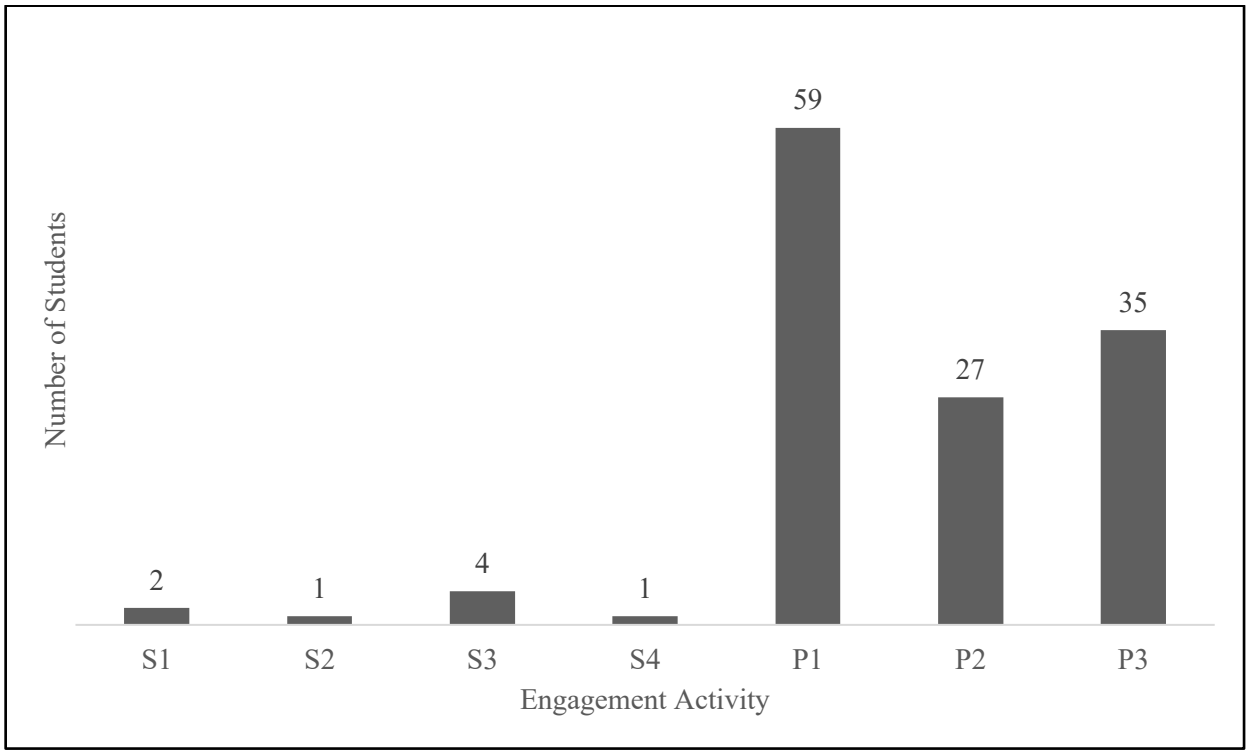

Figure 3. Student engagement at live Q&A sessions using chat and polling features, where S = live Q&A sessions and P = student polling events.

Table 1 lists the poll questions asked at different times during the semester to examine student attitudes. Poll 1 was given after the instructional methods were used in homework assignments, poll 2 was given after the midterm exam which used the same instructional methods as in the homework, and poll 3 was given during the last live question and answer session before the final exam.

Table 1. Poll questions to understand student attitudes.

Poll	Questions
Poll 1	1. Does the "Key terms explanation" help explain key terms? 2. Does the "Key terms explanation" make the key terms easy to understand? 3. Does the figure explanation help explain the picture? 4. Do you think the explanations will help in the exams?
Poll 2	1. Was the Midterm easy to read and understand? 2. Were the figure pictures in the Midterm easy to understand? 3. My weak English skills affected me during the test? 4. My weak Physics skills affected me during the test? 5. Were the Midterm problems hard to solve?
Poll 3	1. I'm confident about the Final Exam.

The focus of poll 1 was to evaluate student attitudes about the instructional methods used in the homework assignments. These methods were first implemented in Homework 3 and the results of Poll 1 are shown in Fig. 4. For questions 1 to 3, the students predominantly said that the instructional methods helped explain and understand key terms by "a little" or "a lot" (between

96-98% positive response). For question 4 regarding whether the student felt that the explanations would be beneficial in an exam, the students also responded positively with 92% saying it would help them “a little” or “a lot”. Thus, the instructional methods were kept for the remaining homework assignments (Homework 4 to 7) and incorporated into the midterm and final exams.

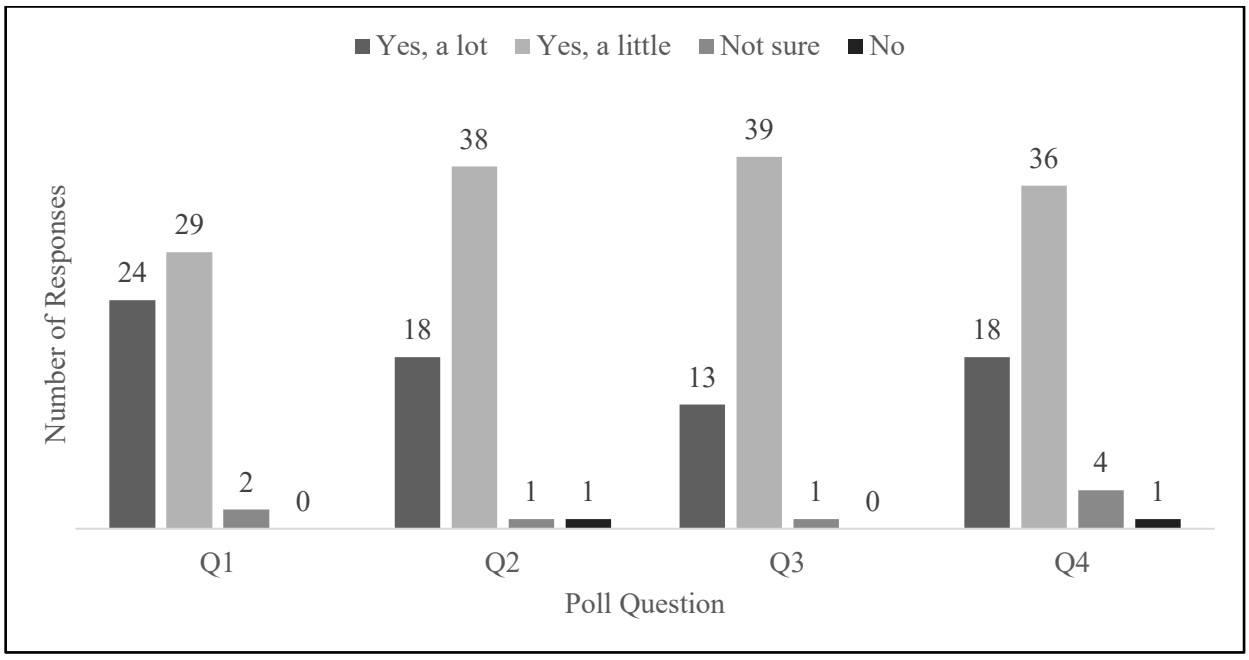

Figure 4. Poll 1 results of student attitudes about instructional methods used in Homework 3. Questions 1 and 2 were aimed at the key terms explanations, question 3 at the figure explanations, and question 4 at whether the explanations would help in the midterm exam.

Homework submission is historically not very high in the present Mechanics of Materials course, so it was important to determine whether homework submission was affected by the instructional methods used. In other words, would students more likely submit their homework if they felt that it was much easier to understand? Homework 1 and 2 served as the control set since they used none of the instructional methods, while Homework 3 to 7 did. Figure 5 shows the submission rates for all seven homework assignments. The results for Homework 3 to 7 show a negligible change overall compared to Homework 1 and 2. Even though Homework 4 had a 100% submission rate, Homework 3, 4, and 7 all had a similar submission rate compared to Homework 1. Homework 6 had a slightly higher submission rate than all the others except Homework 4**.** Despite Homework 1 and 2 having a submission rate above 95%, the results show that the instructional methods did not positively or negatively affect submission rate.

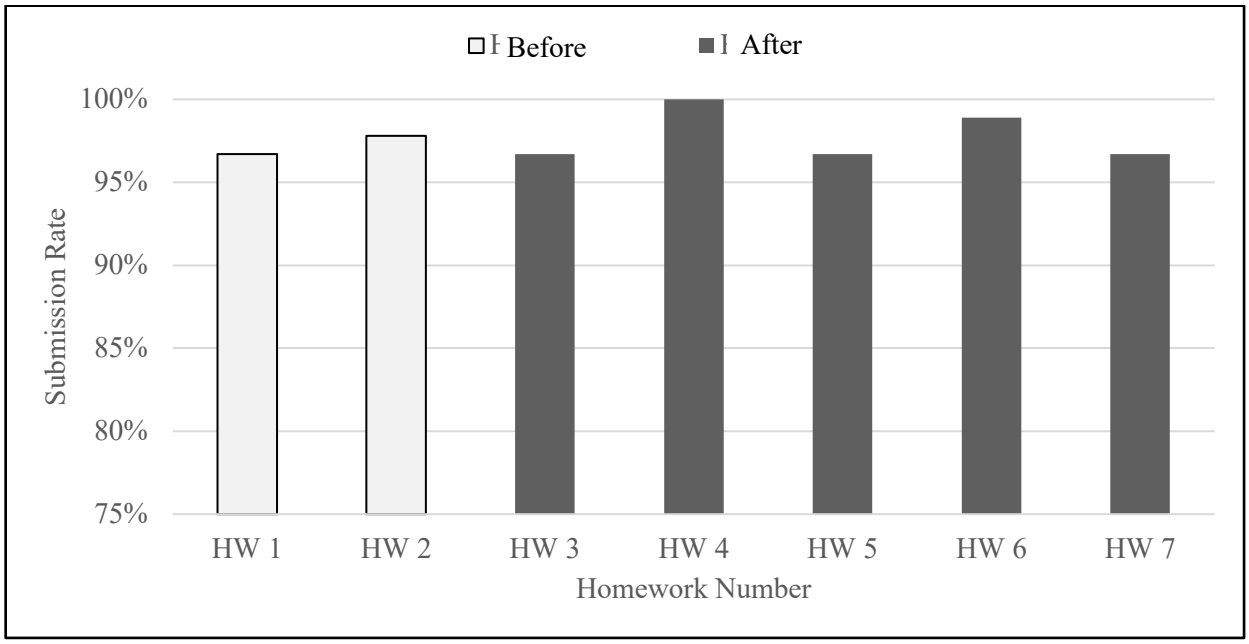

Figure 5. Homework submission rate before and after implementation of instructional methods. HW 1 and HW 2 were assigned without the proposed instructional methods, while HW 3-7 did. The submission rate before and after remained consistently the same.

The focus of Poll 2 was to evaluate student attitudes about the instructional methods used in the midterm exam. Figure 6 shows the results of Poll 2. Questions 1 and 2 were structured like questions 2 and 3 from Poll 1. Unlike Poll 1, the students predominantly were "not sure" or said "no" that the instructional methods helped them understand key terms (between 74-77% negative response). Outside factors, like test anxiety, could be a reason why students felt like the explanations were not helpful.

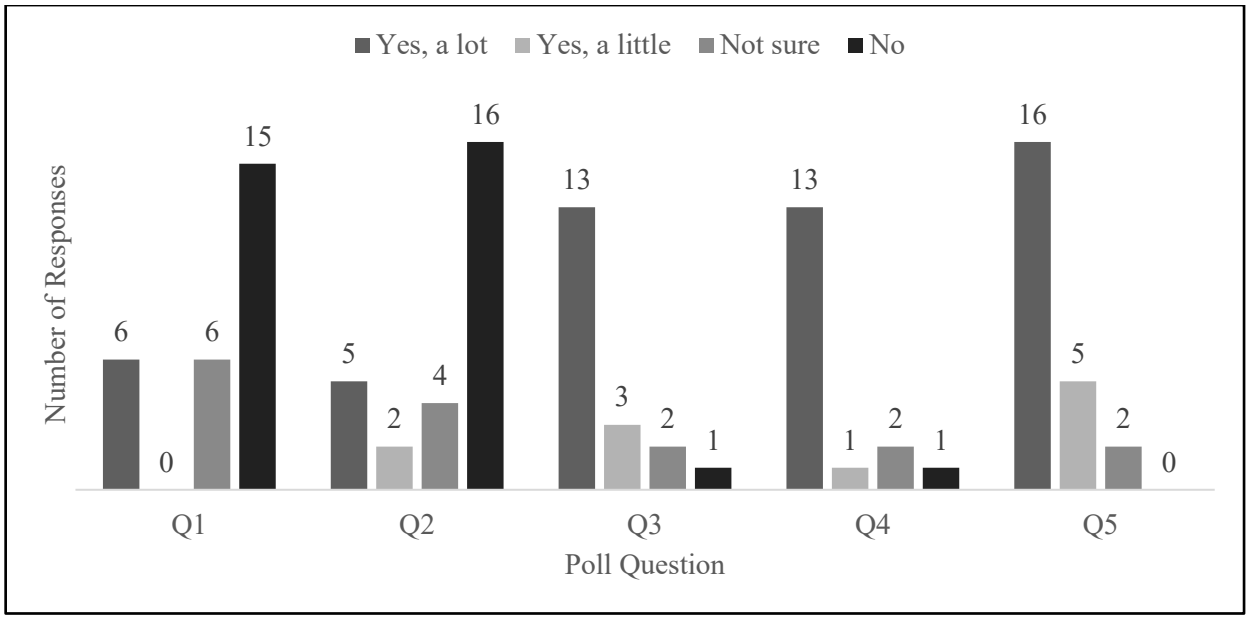

Figure 6. Poll 2 results of student attitudes about instructional methods used in midterm exam. Questions 1 and 2 were aimed at the effect of using explanations on the midterm exam, questions

3 and 4 to student's English and Physics skills, and question 5 about the difficulty of the midterm problems. The number of students responding to poll 2 were half compared to poll 1.

Questions 3 and 4 explored the student attitudes about whether their English proficiency and preparedness in the course with Physics skills affected their performance in the midterm exam. The response to both questions was strongly in favor of "yes" either by "a lot" or "a little" (84% and 82%, respectively). It is possible that factors, like self-identity and perceived lack of preparedness, contributed to the high agreement response. Yet, the class average on the midterm was a 66.5 with a median score of 67.3, so these performance values are consistent with the poll results. Question 5 asked about the perceived level of difficulty of the midterm problems. Students strongly felt that the problems were difficult to solve (91% agreement response), which is further consistent with the student performance results and responses to poll questions 3 and 4. Analysis of Poll 3 was not performed.

The final research question considered whether homework completeness translated to good performance on the midterm and final exams. Homework grading is generally subjective, and consistency is affected when multiple people grade an assignment (e.g., a teaching assistant and an instructor). So, homework assignments were graded on a completion basis. In other words, if a student made an earnest attempt to solve the problem and present a final answer, then full credit for that problem was awarded. A student's grade from a completion perspective was more indicative of their attempt to submit a homework assignment, which was then compared to the student's performance in the midterm and final exams.

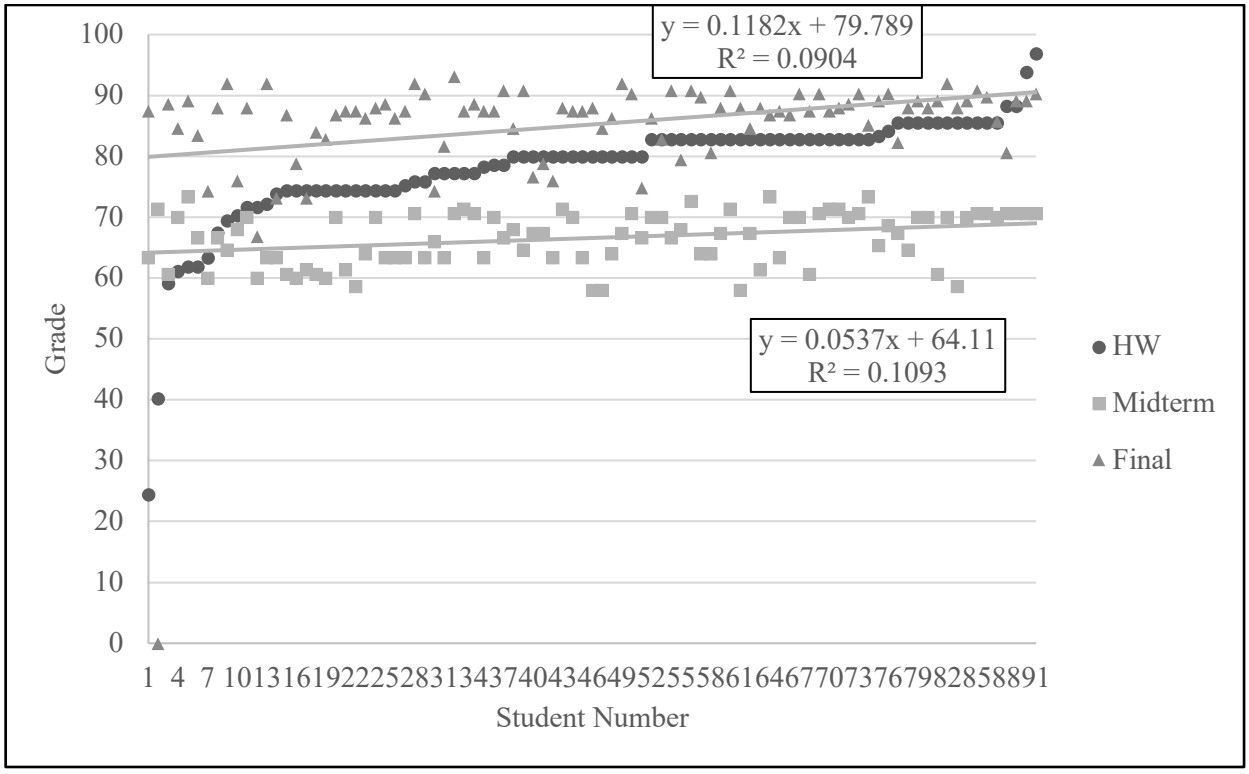

Figure 7. Midterm and final exam scores for each student with respect to homework completion. The trendlines for the midterm and final exams showing a positive increase relative to homework completion.

A comparison to the overall grade in the course was not performed since the homework score is factored into the overall grade calculation and would influence the correlation. The results are presented in Figure 7. All data was sorted with respect to the homework average for the seven homework assignments. The midterm scores showed a weak positive correlation. There was a small indication that students that completed more homework (grade 80 or higher) also did well on the midterm. The average and median score on the midterm was a 66.5 and 67.3, respectively. While the final exam scores also showed a weak positive correlation, the final exam was more indicative of a positive outcome with higher homework completion. The average and median score on the final exam was an 85.2 and 87.4, respectively.

Conclusions

This work developed and implemented a simplified instructional methodology in a Mechanics of Materials course with EFL students. The instructional methods comprised a guided work mapping, figure explanations, and reduced question sets. The methods were used in homework assignments, midterm, and final exam to improve understanding of key terms and decrease cognitive load. Homework submission rate was examined but showed no positive or negative impact from using the instructional methods. The performance results from the midterm exam were low (66.5 average), which was consistent with student feedback—students felt that the explanations were not helpful, and that the problems were difficult to solve (91% agreement response). Further investigation is needed to consider whether factors, such as test anxiety, first exam with new instructor, and perceived lack of preparedness contributed to the poor midterm performance. An encouraging observation was the improvement in performance from the midterm to the final exam (average increased from 66.5 to 85.2). A weak positive correlation was identified between homework average, which was graded on completeness, and a student's performance on the two exams. Thus, a positive outcome in the course could be achieved with higher homework completion.

Since student engagement was also known to be low in the course, the chat forum and poll features in the learning management system were purposely used. The chat forum did not show a positive or negative trend in student engagement and the polling showed an initial appeal to students with a 64.8% response rate. Even though the response rate decreased in subsequent polling, possibly due to passive learning behaviors, the results reveal the benefits of using polling in classes with EFL students for increasing student engagement. Also, conducting more live Q&A sessions or office hours could help improve student engagement.

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