WIP: Development of an Open Education Engineering Mechanics Homework System

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WIP: Development of an Open Education Engineering Strength of Materials Homework System

Abstract:

This Work in Progress Paper highlights the development of an open educational resource at a large mid-Atlantic research university for a foundational strength of materials class. This resource is part of a larger suite of strength of materials tools that have been developed over the last two years, including a textbook and associated problem database, and expands the suite of tools to include Learning Management System integration and assessment feedback.

Instructors can assign individual homework problems and groups of problems in a homework batch to students, with settings available for the number of attempts permitted, due dates, type of feedback given to students, and gradebook integration within the Learning Management System. Students can solve a system of equations for homework problems using an equation builder toolkit with custom variable entry and receive feedback.

The homework system was piloted over three homework assignments in the Fall 2025 semester with approximately 80 students. Spring 2026 will have a full rollout of the homework system for all homework assignments for around 150 students. Student feedback on the open educational resource suite is collected via class surveys and used to inform future development of the resources.

In keeping with the objective of open educational resources, the homework system will be hosted under a Creative Commons license in GitHub following the completion of initial system development in May of 2026. This open educational resource for strength of materials helps to inform educators on additional technology enhanced assessment of large class sizes and can be adopted and integrated directly into the learning management system to promote seamless interaction with the tool by students.

Introduction:

Open Educational Resources (OER) continue to be a supportive avenue for students in learning course content while maintaining an accessible educational environment. With textbook prices continuing to rise around 6% annually [1] in line with rising tuition prices [2], alternative methods of instruction and education need to be sought out for students. Defined as "learning, teaching and research materials that reside in the public domain that permit no cost-access, adaptation, and redistribution by others" [3] OER provides an avenue for students to access resources such as a full textbook, problem exercises, and even software at no cost to them.

Previously for strength of materials, a peer reviewed OER textbook was developed and piloted in a middle year strength of materials class at a large mid-Atlantic university [4]. Following the work of designing and implementing this textbook, a homework system was designed with equation builder functionality for students, with direct integration into the Canvas learning management system [5]. This work continues the Canvas integration, incorporating instant feedback for students, gradebook integration, and the ability to batch assign or group problems.

Through Fall 2025 and Winter 2026, 159 problems have been developed into a database file for integration into the Canvas learning management system. During Fall 2025, 15 problems were piloted with approximately 85 students over three different homework assignments. The full compendium of 159 problems will be piloted with 150 students over 15 homework assignments during Spring 2026. Across two sections with approximately 75 students each, students will be able to complete OER strength of materials problems directly in Canvas, get instant feedback on their work, and see the progress they have made throughout a homework batch without requiring instructor input. Along with reducing the grading strain on faculty in these large courses [6-7], instantaneous feedback will help students to better understand their mastery of the subject [8-9] and engage with gaps in their learning without having to wait for homework feedback.

As such, this study aims to answer the following know-how question:

How can a database of OER problems for strength of materials be integrated into a learning management system for instantaneous feedback?

Literature Review:

Previous Strength of Materials Studies:

Student and faculty perceptions of large engineering classes have been studied extensively. The study by Soledad et al. focused on student perceptions for these classes, specifically on the student perceptions of teaching surveys which occur at the end of a course [10]. Soledad et al. found that while students felt that the instructors of these large engineering courses cared about students and their success, students still struggled with the content in strength of materials courses. Soledad et al. also ran a study on the faculty perceptions of teaching large engineering classes. In this study, Soledad found that faculty generally used group work, cognitive modeling, scaffolding, demonstrating practical applications, and using reinforcers to help students grasp the concepts in middle year engineering courses [11].

A commonly mentioned challenge by both students and faculty in middle years engineering courses are the homework associated with these courses. Lura, O'Neill, and Badir ran a three-part study on homework methods in strength of materials [12-14]. In this study, Lura et al., implemented a series of in class quizzes which replaced the traditional homework assignments due to students feeling homework was overly difficult, took too much of their time, and had low correlation with assessment in class. Despite this initial implementation, Lura et al. found that handwritten homework solutions, frequent in class quizzes, and Pearson's Mastering Engineering software all led to similar student exam scores.

The idea of online homework for strength of materials has been studied previously. Head, Owolabi and James-Okeke found that students who used Pearson's Mastering Engineering online homework software performed better in class, with grades increasing by 1.8% to 17.4% [15]. Despite the evidence that Pearson's Mastering Engineering online software is helpful for students in performing well in these challenging engineering courses, the additional cost of this software, and the short-term subscription of only one semester have been reported as burdens and barriers for students in the course [4].

Previous Engineering OER Studies:

Moore and Reinsfelder's study on the current usage patterns of OER in strength of materials found that adoption and application is currently limited [16]. Despite low current adoption, knowledge of OER was high for instructors, with many reporting an interest in using OER in their classes. The largest barrier of adoption was the lack of quality OER content being developed for strength of materials.

d'Entremont et al. found that existing OER tools for middle-year engineering often did not contain enough practice problems, with major textbooks offering 3000+ practice problems [17]. Despite smaller resources being available for OER tools compared to published for profit textbooks, d'Entremont et al. found that a combination of three engineering instructors, WeBWorK, and Mobius enables engineering faculty to create a rapid pipeline of developing new problems for strength of materials.

Khodadadi found that structural engineering more broadly lacked sufficient representation for OER tools and resources [18]. In their study, Khodadadi similarly stated that despite a current development gap for OER in strength of materials, it is possible to use student experiences and learning outcomes to help inform the design of OER textbooks in strength of materials. The combination of support for developing new OER resources for strength of materials as stated by Khodadadi, Moore, and Reinsfelder, and the ability to rapidly develop and integrate strength of materials problems into OER tools as stated by d'Entremont et al. help to motivate this study. The creation of the homework environment in a commonly used learning management system will allow instructors at all institutions to be able to adopt and support OER tools for strength of materials at their university.

Methodology:

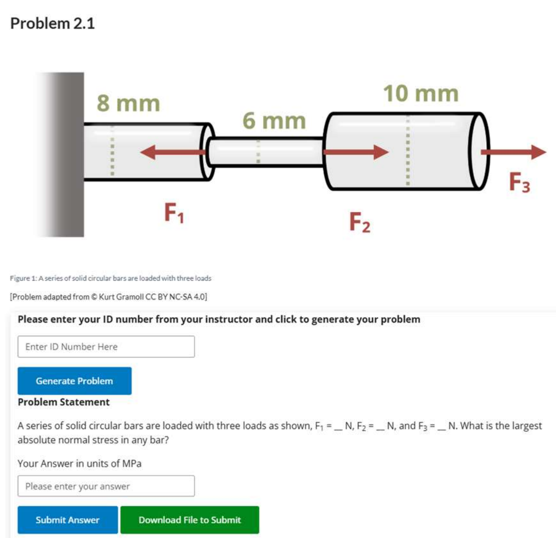
Problem Generation:

A rich bank of problem exercises is often a major gap between engineering OER and popular commercial offerings. Faculty use problems for homework, for in-class exercises, and for assessing learning via quizzes and tests. Quality problems highlight the mechanics implicit in authentic engineering situations and span a range of difficulty so that learning can be scaffolded with practice. Our project has ambitious aims for a problem bank that would approach the comprehensive portfolio of publisher systems. Initially, we hosted faculty from other state institutions who teach deforms for an in-person workshop to write and test problem exercises together. We quickly discovered that while the ideas and contributions of this team were quite meaningful, editing for some stylistic similarity and filling in topical gaps was going to leave a significant amount of work for the core team that would hinder early attempts to pilot the materials. Fortunately, we negotiated permission to adapt a problem bank from the existing Multimedia Engineering Mechanics of Materials textbook [19]. These problems had been used extensively in classes years ago and while the textbook interface was developed in the 2000s, the problem exercises have also been offered in free downloadable applications for mobile devices (e.g., Google Play, Apple App Store). The workflow for this adaptation included parameterizing the problems (e.g., enabling students to have different problem values), re-drawing problem figures for uniform style with our book and to conform to modern accessibility standards (e.g., adding alternative text), and encoding the problems and solutions in R for rendering in HTML and inside of Shiny Apps which would serve individualized problems and enable right/wrong feedback.

We initially added 358 problems were into the system and an early build of these problems is shown below in Figure 1. It is difficult to estimate the time and financial cost on a per problem basis as we certainly developed efficiencies over time. However, at minimum, the team included a faculty author who parameterized problems and set meaningful ranges/steps (e.g., r between 10-15 mm in steps of 0.5 mm), an undergraduate wage graphics artist who would update and redraw figures, and a graduate student with expertise in engineering who could facilitate problem encoding and testing. As highlighted in the Acknowledgements section, the content creation portion of this project has been supported by two Virginia's Academic Library Consortium through the Virtual Library of Virginia (VIVA) grants which in total have provided $80,000 of support. While this financial support included a scope of work well beyond just problem adaptation, we do believe that writing or adapting the volume and quality of problems as we have in this project requires significant time and support that would be challenging to replicate as a faculty member working in isolation or within the regular demands of one's teaching duties.

Figure 1

Initial Homework Software Build for Problem 2.1 in OER Strength of Materials



Database Creation:

Following the initial R coding of 159 pilot problems, a large database was created which combined the problem attributes from the R code with the solutions from Multimedia Engineering Mechanics of Materials and necessary equations students must use to solve the problem. Specifically, the fields in Table 1 below were required for each problem instance:

Table 1

Required Attributes for Each Problem Loaded in the Database for OER Strength of Materials

Property	Definition	Example
Chapter ID	Two digit section number in the format of chapter.section	2.1
Chapter Name	Name of the chapter in the book for which the homework is assigned	Average Normal Stress
Problem ID	Two to three digit unique identifier for problems in the chapter.problem format	2.1
Problem Text	Statement rendered for students when they open a problem explaining the problem and what to solve for	A series of solid circular bars are loaded with three loads as shown, F1 = _ N, F2 = _ N, and F3 = _ N. What is the largest absolute normal stress in any bar?
Variable Range	Symbol, minimum, maximum, and step values for parameterized variables	F1_50-70_1
Variables	Symbol for variable being initialized	d3
Variable Value	Numeric or symbolic value for the variable being initialized. Numeric for static, symbolic for parameterized	10
Variable Units	Units for the preceding variable defined	mm
Equations	Symbolic forms of each step needed to solve a problem	FBC = F1-R

Answer	Answer to the problem in symbolic format based on loaded variables and equations	max(sigmaAB, sigmaBC, sigmaCD)
Answer Units	Units of the final answer for the problem	MPa

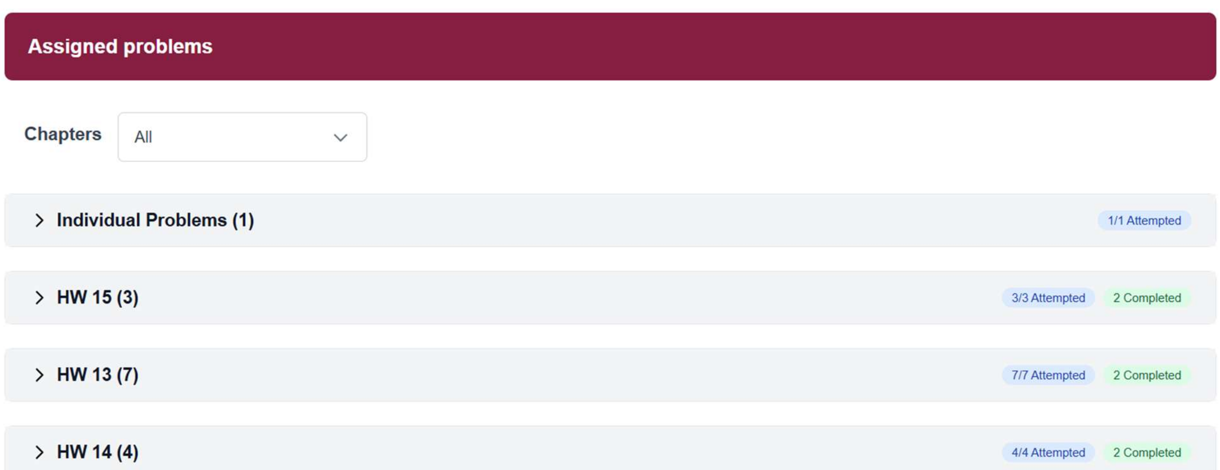
Database rows were generated by undergraduate engineering students supervised by a graduate engineering student and verified by strength of materials subject matter experts before being sent for integration into Canvas.

Canvas Integration:

At the mid-Atlantic university conducting this research, Canvas is the learning management system used by the students. Thus, integration into Canvas was the goal for both students and faculty involved with strength of materials. The first step of Canvas integration was creating a user interface for the students where they could access a dashboard of all problems assigned to them. Figure 2 below shows the current build of this interface:

Figure 2

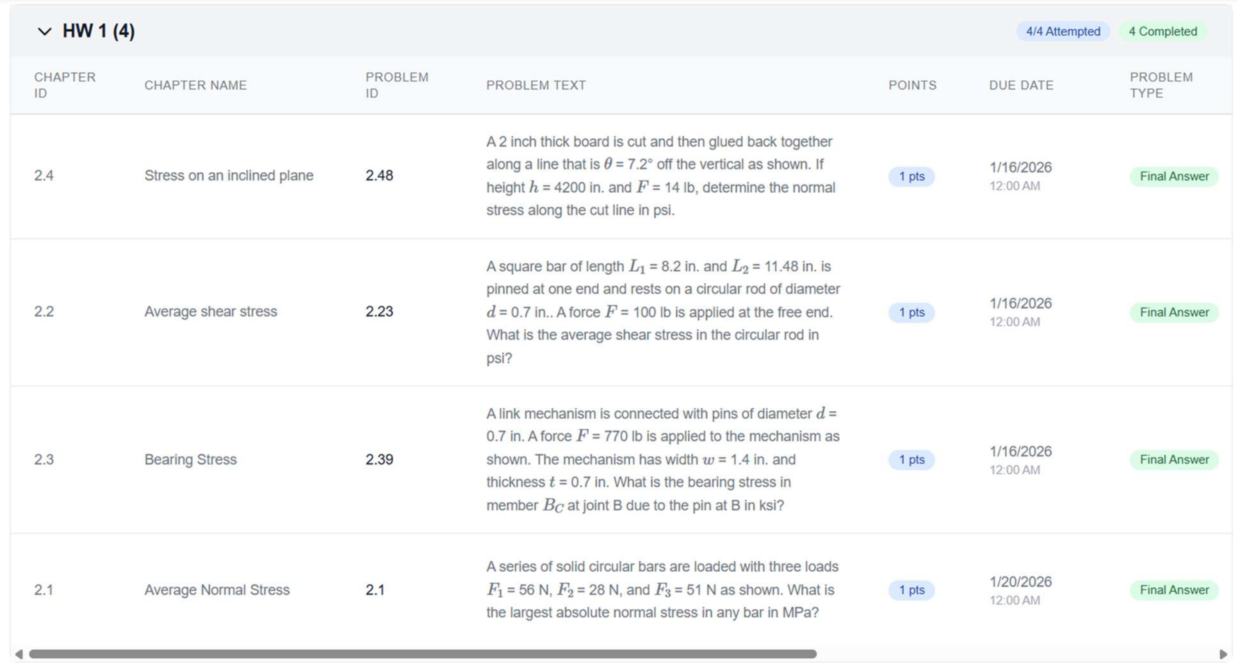
Problem Dashboard in Canvas for OER Strength of Materials



Once students select a homework assignment from this interface, they will see each problem assigned in that batch and the following information for each problem:

Figure 3

Expanded Homework Batch in Canvas for OER Strength of Materials



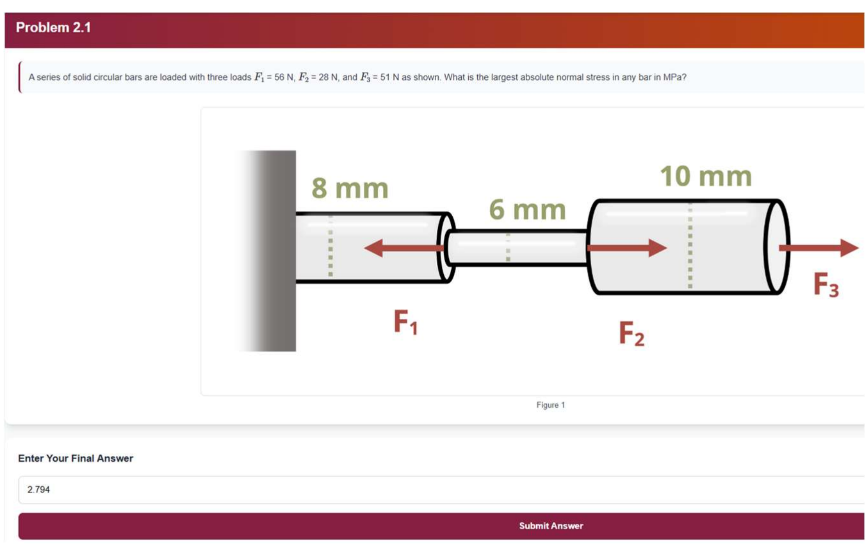
HW 1 (4) — 4/4 Attempted — 4 Completed

CHAPTER ID	CHAPTER NAME	PROBLEM ID	PROBLEM TEXT	POINTS	DUE DATE	PROBLEM TYPE
2.4	Stress on an inclined plane	2.48	A 2 inch thick board is cut and then glued back together along a line that is θ = 7.2° off the vertical as shown. If height h = 4200 in. and F = 14 lb, determine the normal stress along the cut line in psi.	1 pts	1/16/2026 12:00 AM	Final Answer
2.2	Average shear stress	2.23	A square bar of length L_1 = 8.2 in. and L_2 = 11.48 in. is pinned at one end and rests on a circular rod of diameter d = 0.7 in.. A force F = 100 lb is applied at the free end. What is the average shear stress in the circular rod in psi?	1 pts	1/16/2026 12:00 AM	Final Answer
2.3	Bearing Stress	2.39	A link mechanism is connected with pins of diameter d = 0.7 in. A force F = 770 lb is applied to the mechanism as shown. The mechanism has width w = 1.4 in. and thickness t = 0.7 in. What is the bearing stress in member B_C at joint B due to the pin at B in ksi?	1 pts	1/16/2026 12:00 AM	Final Answer
2.1	Average Normal Stress	2.1	A series of solid circular bars are loaded with three loads F_1 = 56 N, F_2 = 28 N, and F_3 = 51 N as shown. What is the largest absolute normal stress in any bar in MPa?	1 pts	1/20/2026 12:00 AM	Final Answer

Once students open a problem, they will be shown the problem figure, the problem statement, and a dialog box where they can submit their answer to the problem for verification. Some values in problems are static, that is the same for each student, while others are dynamic, different for each student, but are prerendered for when students open the problem. The instance for the problem shown in previous figures in this new environment is shown below in Figure 4:

Figure 4

Canvas Software Build for Problem 2.1 in OER Strength of Materials



Once students attempt a problem, they get instant feedback on their solution based on the value calculated using the equations in the database. A tolerance of +/- 1% is given to the mathematically determined answer by the database, to account for small rounding/significant figure difference used across students. Figure 5a shows an example of what an incorrect answer shows up as and Figure 5b shows an example of what a correct answer shows up as.

Figure 5a

Incorrect Answer Example in the Canvas Environment for OER Strength of Materials

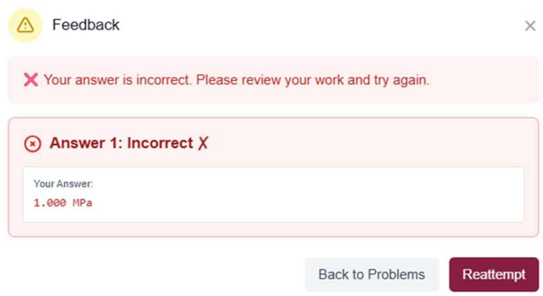
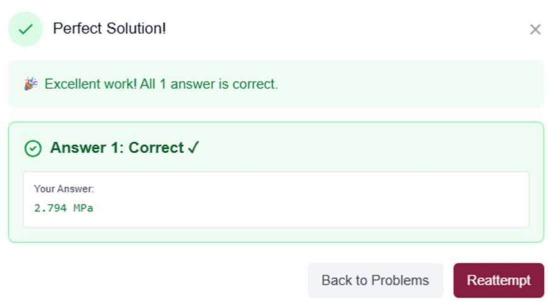


Figure 5b

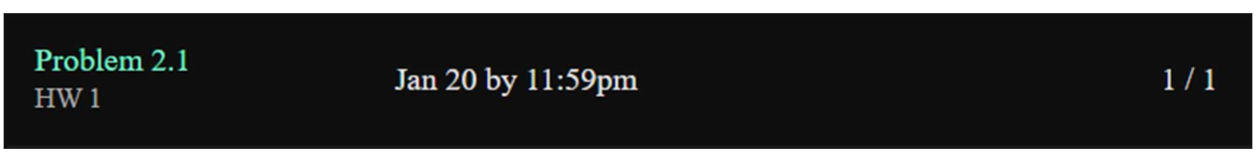
Correct Answer Example in the Canvas Environment for OER Strength of Materials



The results of the problem attempt are also linked to and reflected in the Canvas gradebook for each student as shown below in Figure 6:

Figure 6

Gradebook Screenshot from Canvas for OER Strength of Materials



Instructors also have some control in the problems with attributes including the problem due date, if the problem can be attempted after the due date, how many points a problem is worth, the type of problem submission they are expecting from the students, the number of attempts a student has on a problem, and any penalty for an incorrect attempt on a problem. Currently, the software supports “Final Answer” where students just submit one value to determine if it is right or wrong.

Preliminary Results:

Student Feedback:

For the one section of the class in Fall 2025 which was given the three homework problems in Canvas, feedback was largely positive. Students claimed that they “liked the Canvas implementation”, “no significant issues or errors occurred”, and “all problems could be accessed and worked on”.

Critical feedback on the Canvas implementation for OER strength of materials was largely on the functionality of how problems were accessed or showed up in the system. One comment was noted that after attempting a problem, regardless of it being right or wrong, the software would kick users back to the dashboard page. In response, a reattempt button was added as shown in Figures 5a and 5b. Students also mentioned that a status indicator should be added to show them if the problem was attempted and correct, attempted and not correct, or not yet attempted would be helpful to include. An example of this feature for each instance is shown below in Figures 7a, 7b, and 7c:

Figure 7a

Screenshot of Problem Attempted With a Correct Solution in Canvas for OER Strength of Materials

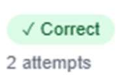


Figure 7b

Screenshot of Problem Attempted With an Incorrect Solution in Canvas for OER Strength of Materials

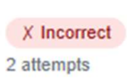


Figure 7c

Screenshot of Problem Not Yet Attempted in OER Strength of Materials

Instructor Feedback:

The instructor of the sections of the Fall 2025 class mentioned "it was easy to operate from the instructor side", "there were no significant issues creating and assigning the homework", and "it was overall a very positive experience".

Critical feedback on the implementation was mostly focused on how the instructor sees the assignments and scores within Canvas itself. In the initial build, problems were batched in the interface shown previously in Figure 2, but in the Canvas gradebook showed up as individual problems and caused clutter. These were then regrouped pre assignment with attempted scores summed as shown in Figure 8 below:

Figure 8

Screenshot of Homework 1 Grouping of Assignments in Canvas for OER Strength of Materials

The other requested edit was to assign problems to the Test Student in Canvas as well so that the student view could be shown to the class by the instructor and viewed by instructors so they make sure problems are assigned and setup as intended when given to the students.

Future Work/Conclusions:

Following a successful small-scale pilot in Fall 2025, a full pilot of OER strength of materials in the Canvas learning management system will be taking place in Spring 2026. Approximately 150 students will be able to attempt 159 problems in the environment, with automatic feedback and grading occurring instantaneously for students.

In answering the research question, "How can a database of OER problems for strength of materials be integrated into a learning management system for instantaneous feedback?", an interdisciplinary team of engineering educators, strength of materials faculty, learning technologies specialists, and librarians from the undergraduate level through senior faculty leveraged specialized knowledge to create a pipeline of developing, expanding, and integrating problems into the Canvas learning management system.

Future work includes expanding the bank of problems in Canvas to the full list of 358 problems available in the OER strength of materials compendium, integrating and testing learning analytics data within Canvas for the students, and expanding the solution system to enable equation building and figure creation to provide students with timely targeted feedback via canonical tree methods, equation mapping, and generative artificial intelligence. This would also enable the problem types of "System of Equations" and potentially "Upload Work" to be integrated into the system, to provide a range of problem types for students and instructors to use.

Implications from this work include reducing the grading burden on instructors in large middle year engineering courses to provide them with more time for class preparation and student interactions, providing students with the ability to get instant feedback on their homework to continuously and readily evaluate their learning before major class assessments, and continuing to expand the suite of OER available to engineering students in the ever evolving higher education landscape.

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