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(PREP)ARE: A Student-centered Approach to Provide Scaffolding in a Flipped Classroom Environment

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(PREP)ARE: A student-centered approach to provide scaffolding in a flipped classroom environment

Abstract

This complete Evidence-based Practice paper will detail the implementation of scaffolding to support learning in a flipped-classroom environment. Promoting problem solving skill development is a major focus of the General Engineering (GE) Program at Clemson University, as problem solving is a critical skill required by practicing engineers. The GE Program has utilized a SCALE-UP (Student-Centered Activities for Large-Enrollment Undergraduate Programs) environment for over a decade. SCALE-UP is a highly collaborative, hands-on classroom format where the primary emphasis is on learning by guided inquiry rather than by traditional lecturing. The SCALE-UP learning environments is a natural "semi-flipped" classroom by the nature of the program. When used within a large enrollment program that utilizes several instructors in a single semester, the amount of "flip" will vary with each instructor providing various levels of lecture and activities. The largest hurdle with using a "flipped" environment is getting the students to prepare adequately for class to allow for meaningful classroom discussion. The first course in the GE sequence is composed of more than 90% first time freshman, most of whom have yet to develop a mental model of what preparing for a college course entails.

In Fall 2015, the first-year sequence adopted the (**PREP)ARE** model to assist students in understanding the expectations for each class. The model was presented in a standard course management system across all sections of our first semester problem solving (aka. ENGR 1) and second semester programming (aka. ENGR 2) courses. Each course was divided into learning modules that build off the knowledge and skills developed in prior modules. For each module, students were instructed to **PREP**: **P**review the material; get **R**eady for class; **E**xpand their knowledge; and then **P**rove it by completing the homework. Prior to each exam, students were asked "**ARE** you ready?" and encouraged to answer this question by **A**ssessing their performance on each module by analyzing mistakes made on assignments and asking questions of the instructor for further clarification; **R**eviewing any topics not mastered; then taking the **E**xam.

This work will discuss the (PREP)ARE model in detail, giving examples of activities for each stage to illustrate the breadth of applicability to first-year course material. Examination results, student/instructor attitudes, and course DFW rates will be compared between courses using this method to prior courses.

Background

The major focus of the General Engineering (GE) Program at Clemson University is to teach students how to think like an engineer in preparation for entrance to their chosen discipline of engineering major. Program achievement metrics evaluate student-learning gains across four domains: 1) Problem Solving, 2) Digital Literacy, 3) Communication, and 4) Self-awareness.

Students enter the program from a wide range of academic backgrounds and exposure to technology. In an effort to manage this variance, GE has implemented a flipped classroom using SCALE-UP activities in class to strengthen student performance on problem solving activities.

The GE Program has utilized a SCALE-UP (Student-Centered Activities for Large-Enrollment Undergraduate Programs) environment for over a decade; breaking from the orthodoxy of traditional lecture to incorporate a highly collaborative, hands-on format where the primary emphasis is on learning by guided inquiry. This essentially shifts content delivery of basic foundational knowledge to time outside of the classroom; utilizing class time for supervised skill development and tips from instructors' professional experiences. Using SCALE-UP facilitates real-time assistance from instructors or teaching assistants, helping students overcome hurdles with lessened frustration than if they were completing the exercise alone. SCALE-UP is a highly collaborative, hands-on classroom format where the primary emphasis is on learning by guided inquiry rather than by traditional lecturing [1, 2, 3, 4].

While SCALE-UP affords a natural "semi-flipped" classroom environment, when used within a large enrollment program that utilizes several instructors in a single semester, the amount of "flip" will vary with each instructor providing various levels of lecture and activities. This is an issue especially in large-enrollment programs, such as Clemson GE. In Fall 2017, the first-semester course (Engineering I) was conducted with 1173 students, 26 sections, and 11 instructors.

The (PREP)ARE module structure mitigates the consequences of variation in teaching styles across instructors when implemented for all sections. By using a basic course outline for the template for all sections of the course, instructors begin with a setup that would already be sufficient for students to achieve course-learning outcomes. This frees up class time for instructors to spend more time focused on resolving individual student questions. Students still have access to the same content and problem solving assignments, just with an innovative learning environment that allows for, in our opinion, a better utilization of time resources.

(PREP)ARE Modular Structure

The largest hurdle we experience with a "flipped" environment is getting students to prepare adequately for class. The (PREP)ARE module structure, shown in Figure 1, was developed as a way to manage the presentation of content, clarify course objectives and expectations, and enable personalized learning opportunities needed to level the playing field between students so that all students can engage in interactive activities with a sense of confidence and autonomy. This program was based on a concept called GEARSET (General Engineering Assessment Record Self-Evaluation Tool), previously utilized at Clemson University [5].

Modules break the course into manageable units, where each subsequent learning module builds off the knowledge and skills developed in prior modules. Ideally, modules contain one week's worth of related content. The (PREP)ARE structure works similarly to trail markers, guiding students through the content, setting pace, providing direction, and ensuring access to information for all users.

For each module, students were instructed to **PREP**:

- **P**review the material;
- **R**eady yourself for class;
- **E**xpand your understanding; and
- **P**rove it by completing the homework.

The module starts by exposing students to the content and assessing they performed the activity. The *"Preview"* activities were either scored but not included in the course grade, graded on participation, or graded with another form of holistic rubric. These micro assessments promote self-awareness of knowledge or skills deficiencies, a critical step to learning.
Next students have an opportunity to evaluate their conceptual understanding. Typical *"Ready"* assessments came in the form of reading quizzes or comprehension check problem sets where students are provided immediate feedback on accuracy.

Opportunities to *"Expand"* understanding typically took place as activities, ranging from problem sets, to experiments, to memos on research. This is the area where the instructor has the most influence on content delivery and determination of graded components. Meanwhile, students are guaranteed to be presented with at least the basic material that has been standardized and assigned in the first two steps of the PREP cycle.

The final step has students demonstrate what they have learned, or "*Prove it"*. This assignment, usually in the form of homework, was essentially how students would have received feedback before the implementation of PREP.

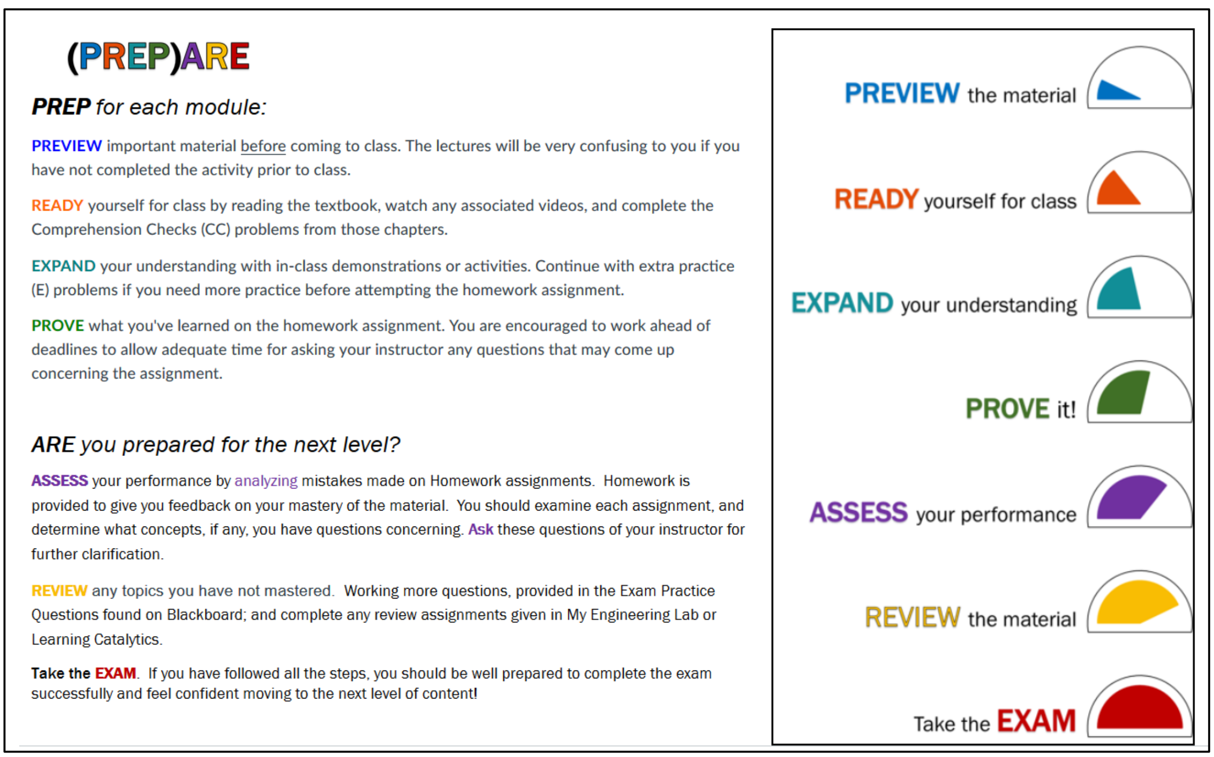


Figure 1: (PREP)ARE modular course structure

In general, students would progress through three or four modules of related content and then have an exam. With (PREP)ARE, we worked to model good study practices and emphasize student self-regulation skills by helping them discover deficiencies before the exam, giving students one more opportunity to self-correct before the major assessment point.

Prior to each exam, students were asked "**ARE** you ready?"

- **A**ssess your performance on each module by analyzing mistakes made on assignments and asking questions of the instructor for further clarification;
- **R**eview any topics not mastered;
- **E**xam as a final assessment of learning.

Implementation of (PREP)ARE modules

The (PREP)ARE module structure was created in Summer 2015 as part of an effort to improve the content delivery for online sections of our courses. The model was iteratively refined over the course of three mini-terms and implemented for both ENGR 1 and ENGR 2 courses in Fall 2015. The model was provided in a standard presentation to instructors in a template through the course management system and was rolled out to all sections of a course. An example of the overview of a module on units and dimensions from ENGR 1 is shown in Figure 2.

Module 2: Units and Dimensions

		What	Where	When
Preview	Read	Chapter 7.1 - 7.5, 7.8 pages 167 - 179, 187 - 189		prior to class on Fri, 8/25
	Write	Download Reading Guide to take notes Bring to class to add additional notes	(below)	
	Watch	Associated videos	MEL	
Ready	Check	Comprehension Check (CC2)	MEL	
	Quiz	Pre-Quiz 2		
Expand	Work	Additional Practice (AP2) *Required if PQ < 80% but encouraged regardless of PQ score*	MEL	prior to class on Mon, 8/28
	Ask	questions to your instructor, if necessary	Email, office hours, or class	
Prove	Complete	Homework (HW2) *Email* instructor if PQ<80% and AP<60% to unlock HW*	MEL	Tue, 8/29 @10pm on MEL Hardcopy of assignment due @start of class on Wed 8/30

*Requests made after 5pm may not be received.

Learning Objectives

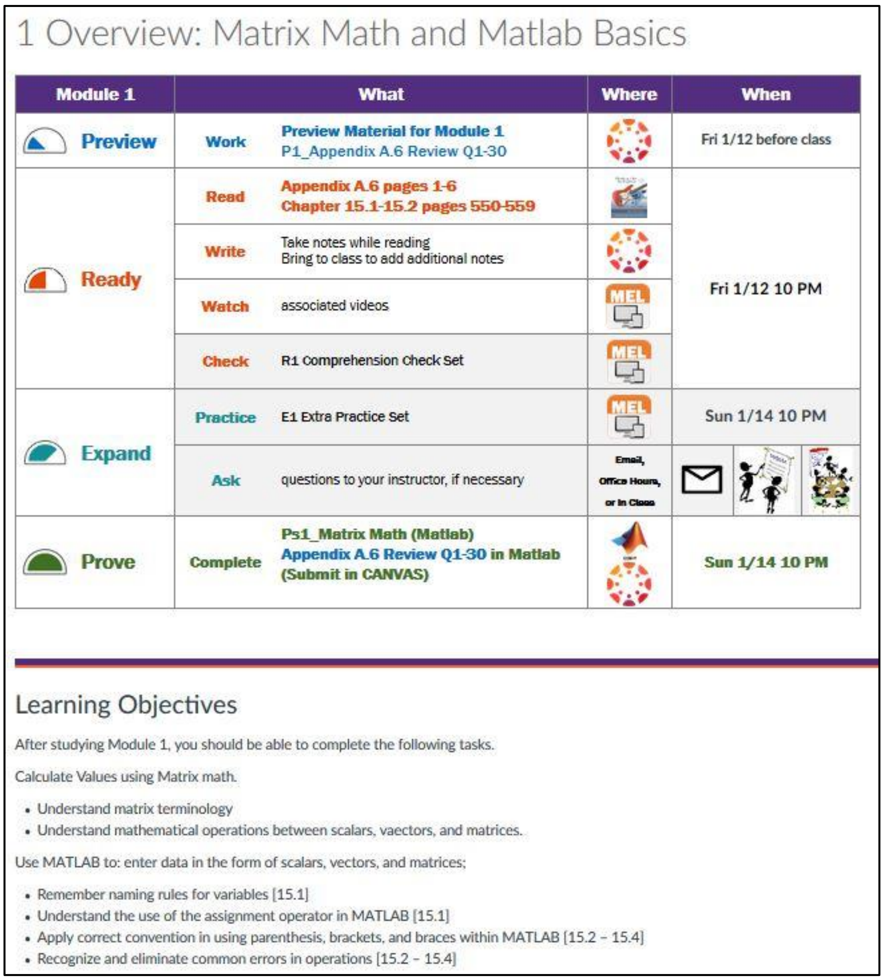
After studying this module, you should be able to complete the following tasks. If you require more practice on any topic, see the Exam Practice Questions in the Exam 1 Module.

Chapter 7.1

- Express quantities using correct SI prefixes
- List the seven fundamental dimensions and their symbol
- List the seven base SI units, their symbol, and the matching fundamental dimensions
- Identify a quantity as a dimension or a unit
- Express units correctly using the official SI rules

Figure 2: An example (PREP) Module Overview for Engineering I. There are more leaning objectives for the module; only the first chapter section is shown for space considerations.

MyEngineeringLab (MEL), a web-based homework management system accessed by students as a companion site to the course textbook was used as a tool for managing the progression of students from one assignment to the next, providing pre-requisite checking and real time assessment [6]. MyEngineeringLab is part of the MyLab and Mastering suite of products operated by Pearson Higher Education [7]. These features allowed instructors to personalize requirements by allowing students to skip "expanding" on the material and proceed straight to the homework if they proved mastery on the preview material by meeting a threshold performance level on the "*Preview*" timed quiz. For the programming course, instead of pre-quizzes, students work through a "*Preview*" coding activity with basic content in preparation for class. Students must decide on their own whether they need to complete the "expand" step and complete additional practice before attempting the homework. An overview of the first (PREP) module for the programming course is shown in Figure 3 for comparison.



1 Overview: Matrix Math and Matlab Basics

Module 1		What	Where	When
Preview	Work	Preview Material for Module 1 P1_Appendix A.6 Review Q1-30		Fri 1/12 before class
Ready	Read	Appendix A.6 pages 1-6 Chapter 15.1-15.2 pages 550-559		Fri 1/12 10 PM
	Write	Take notes while reading Bring to class to add additional notes		
	Watch	associated videos	MEL	
	Check	R1 Comprehension Check Set	MEL	
Expand	Practice	E1 Extra Practice Set	MEL	Sun 1/14 10 PM
	Ask	questions to your instructor, if necessary	Email, Office Hours, or in Class	
Prove	Complete	Ps1_Matrix Math (Matlab) Appendix A.6 Review Q1-30 in Matlab (Submit in CANVAS)		Sun 1/14 10 PM

Learning Objectives

After studying Module 1, you should be able to complete the following tasks.

Calculate Values using Matrix math.

- Understand matrix terminology
- Understand mathematical operations between scalars, vaectors, and matrices.

Use MATLAB to: enter data in the form of scalars, vectors, and matrices;

- Remember naming rules for variables [15.1]
- Understand the use of the assignment operator in MATLAB [15.1]
- Apply correct convention in using parenthesis, brackets, and braces within MATLAB [15.2 – 15.4]
- Recognize and eliminate common errors in operations [15.2 – 15.4]

Figure 3: Example layout of a module overview page for Engineering 2, with assignment names coded to match the PREP cycle stage. There are more leaning objectives for the module; only a few are shown for space considerations.

Results and Discussion

Student pass rates from ENGR 1 were used to evaluate student success before and after the implementation of the (PREP)ARE modular structure (in combination with other interventions such as the use of the CU Thinking PROCESS [8, 9] for problem solving and Cody Coursework [10], among others) for students of three levels of mathematics preparation.

In the first term, students who do not have Advanced Placement (AP), International Baccalaureate (IB), Dual Enrollment (DE) or transfer credit for Calculus I are placed into a math course based on their Clemson Math Placement Test (CMPT) score. Since 2013, Clemson has used the **A**ssessment and **LE**arning in **K**nowledge **S**paces exam (ALEKS) to assess students for math placement. Students who score lower than 80 place into "Year-Long Calculus", a two-semester sequence used to cover the content of Calculus I [11].

Historically, students in the Year-Long (YL) Calculus have performed poorly in the foundational engineering course (Engineering I). The PREP(ARE) course intervention has had an overall positive impact on student pass rates, with improvements across the board, though the most dramatic improvements have been seem among students taking YL Calculus. Average pass rates rose 16.3% for this group of students taking YL Calculus (Table 1), 8.7% for students taking Calculus 1 (Table 2), and 2.3% for students taking Calculus 2 (Table 3).

Table 1: Course Performance for Year-Long Calculus 1 Students in Engineering I

Fall term	Total Students	% Passed ENGR I	Instructor Materials	Average
2013	129	49.6%	Common Lecture Materials	43.9%
2014	115	37.4%		
2015	121	54.5%	(PREP)ARE module structure	60.2%
2016	123	65.9%		
2017		78.5%		78.5%

Table 2: Course Performance for Regular Calculus 1 Students in Engineering I

Fall term	Total Students	% Passed ENGR I	Instructor Materials	Average
2013	544	73.7%	Common Lecture Materials	78.4%
2014	587	82.3%		
2015	609	87.4%	(PREP)ARE module structure	87.1%
2016	588	86.9%		
2017	547	93.2%		93.2%

Table 3: Course Performance for Calculus 2 Students in Engineering I

Fall term	Total Students	% Passed ENGR I	Instructor Materials	Average
2013	165	90.9%	Common Lecture Materials	93.8%
2014	173	96.5%		
2015	138	97.1%	(PREP)ARE module structure	96.1%
2016	120	95.0%		
2017	87	96.6%		96.6%

The increase in pass rates for the YL Calculus students can be contributed to two factors. First, underprepared students often display an "illusion of comprehension". A strong instructor, acting as the content expert, may give students the illusion of understanding the material. Students leave class thinking they know the material, but they do not [12]. Second, underprepared students may benefit because frequent assessment and feedback helps them monitor their own progress. Two major obstacles for at-rick students are (a) lack of study strategies and (b) not being able to differentiate between essential and non-essential information [13]. The PREP module provides a clear structure to help students determine the "essential" course components.

Widespread implementation resulted in several minor modifications, especially concerning the weighing of grades and use of pre-requisites; however, the core structure remained consistent throughout all sections of the courses and instructors saw value in its use. Instructors appreciate the structure and it has helped to establish a clear timeline for course content delivery. One of our new instructors provided a review of the (PREP)ARE module structure saying, "*as an onboarding professor, it was very helpful to have this material selected a priori. It helped me stay on schedule; without it, I would most likely not have kept up with the pace of the class to provide the students sufficient breadth and depth of material.*"

Unfortunately, when students were asked to rate the effectiveness of the (PREP)ARE modules as a learning aid, they have not responded with as much enthusiasm as expected. On the end of Fall 2017 survey, 51% of Engineering I students answered this question as "N/A", indicating their instructor did not use the structure in their course even though all sections used this model. It appears students simply accept the module structure as a normal feature of the courses and may not be aware of the specifics of the model. As first semester college students, the majority of the respondents have no basis of comparison for course structure and many have not previously used an online course management system. In this case, it may be fair to say the PREP(ARE) structure is unobtrusive and likely contributed to an improvement in pass rate in the first semester engineering problem solving course.

Conclusions and Future Work

The GE program strives to provide a student-centered environment to foster a quality learning experience for our developing engineers through delivering foundational knowledge and facilitating skills development. Part of this requires ensuring a clear understanding of expectations. (PREP)ARE module structure is our best solution to maintaining clear expectations between the instructor and the student for all sections. We will continue to ask students about their perceptions of the effectiveness of learning aides used by our instructors, including (PREP)ARE.

Future work will evaluate the use of this structure and resulting student perceptions of its effectiveness as a learning aid for four different student populations: 1) Online courses; 2) Students who begin the Engineering I course in Year-Long Calculus who are part of a Learning Community (LC) for these students; 3) Residents in Science and Engineering (RiSE) Living-Learning Community (LLC); and 4) General population. This validation effort will ensure the model is effective across topics (problem solving and programming), delivery method (online versus in-person), and learner environment (LC, LLC, General).

We will continue to refine to structure to address concerns such as the low awareness of the module structure and learning objectives. Students will be surveyed again regarding the effectiveness of learning aids including (PREP)ARE in an end of year survey. Hopefully by the end of the second semester of use, students will reported higher awareness. One strategy suggested to enhance awareness of the module structure is through mimicking the stages in assignment names. Additionally, efforts are underway to rework the Assess stage in the *ARE* portion to integrate the learning objectives into the study cycle for exams through use of an early "Exam Wrapper" [14]. Here students will assess their confidence on learning objectives as the first step as a means to help them prioritize what to review for the exam.

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