In-class Active Learning and Frequent Assessment Reform of Nuclear Reactor Theory Course

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Abstract – **We substituted a 10-15 minute quiz followed by active-learning problem-solving activities in place of in-class lectures in a senior level nuclear reactor theory course taken by 32 students in Spring 2004. In-class lectures were replaced by online multi-media streaming video eTEACH presentations that included self-assessment exercises that the students viewed in their own time and place. Our primary goal was to measure the effect of enhanced time-on-task strategies on student attitudes and learning outcomes. The in-class quizzes encouraged students to keep up with the mathematically challenging material and to view the online lectures BEFORE coming to class. The self-assessment exercises in the lectures encouraged students to immediately reflect on the depth to which they understood the material. In-class problem solving gave the faculty opportunities to directly guide students in problem-solving strategies. Student response was measured by a formal evaluation with early and end-of-the-semester surveys.**

Index Terms – Active learning, problem-based learning, eTEACH streaming video, frequent assessment, nuclear reactor theory, time-on-task.

INTRODUCTION

Think Engineering – and you think “hands-on,” “real-world,” and “today.” You think of human-constructed objects and processes. The emphasis is “of human creation.” Engineering by its nature is founded on “active involvement.” Yet our engineering educational practice often mires students in passive lectures and “cookbook” labs where results are predicted from dozens of semesters of prior experiences. Education research-based principles and practices (particularly problem-based and inquiry-based learning) have proven to be superior methods of instruction over conventional lecturing in the classroom. Definitions and descriptions of active learning, collaborative and cooperative learning, problem-based learning, inquiry-based learning, and other practices based upon the constructivist theory of learning have been published [1]-[8]. In this paper, active learning is defined as students engaged in activities that are not passively listening to lectures and taking notes [5]. Most often these activities involve a team-based approach to learning. Problem-based learning organizes student team learning around specific problems created by the professor [9]. It uses the idea that learning is a constructive interactive process and that social and contextual factors influence learning.

Also important to learning outcomes is student assessment. Coming from high school, students are accustomed to frequent (weekly or bi-weekly) in-class quizzes that test recently introduced concepts. Once in college, the assessment pattern changes to one where mid-term and final exams are the sole formal measures of student learning. The argument is often given: “this is now college, the students should have the maturity to take it upon themselves to study the material and should be prepared to demonstrate their competencies over a large body of knowledge such as a half or full semester’s worth.” This point of view ignores that assessment is in fact a positive perturbative measurement of student achievement and in itself has beneficial consequences for student learning. It is not just for the purposes of assigning grades. Frequent assessments give students more immediate feedback on their learning achievements and how these match against expectations. Frequent assessments quickly flag learning difficulties either with a particular subject or for particular students. Early detection of problems can lead to remedial or corrective actions by the instructor and the students. This is particularly important in a course where each week’s lesson is a necessary prerequisite for the following weeks’ lessons. Failure to grasp key concepts midway through a course can derail a student’s performance for the entire course.

Finally, the role of the lecture deserves clarification. Lectures have been portrayed as an ineffective way of teaching because they are often a passive one-way information flow from professor to student, with questionable learning outcomes. However, the same might be said of textbooks, yet textbooks are rarely criticized in the same way. This inconsistency can be resolved by recognizing that a verbal presentation can often be valuable to the learning of students. The issue is one of classroom priority. If a professor has approximately 40 hours of contact with students in a classroom over a semester, what is the most valuable use of that time? Most educators would agree that it is NOT having the students read the assigned pages in the textbook. Research has shown that lectures that include team problem-solving and in-class assessments have positive outcomes [10]. It has also been shown that the use of modern learning technology can replace the in-class lecture with online equivalents, so that the class time can be spent on higher learning priorities [11].

RESTRUCTURING NUCLEAR REACTOR THEORY COURSE

The nuclear reactor theory course offered at the University of Wisconsin-Madison has been taught in its present form by the first author for over 25 years. This is a basic principles course, so there is little change in fundamental content. The focus is on the interaction of neutrons with matter in the specific context of the multiplying media of a nuclear reactor core. The course is very mathematical in its content and requires five semesters of calculus, including differential equations and vector calculus, as prerequisites. A standard textbook is closely followed in most of the lessons. The course is offered once per year, in the spring semester, and is typically taken by 15-35 students. It is taught in a typical classroom, in recent years with computer and computer projector available. Until Spring 2003, the course was taught with the standard in-class lecture style. Students were assessed by 13 weekly homework assignments and a mid-term and final exam.

The goals of the reform were to demonstrate that time-on-task was important to student learning and to measure the student learning outcomes. Four basic reforms were included in the experiment.

- In-class lectures were replaced with online streaming-video eTEACH [12] presentations.
- The eTEACH presentations included self-assessment exercises.
- Every class period started with a 10-15 minute open-book and open-notes quiz, covering the content of the day's online eTEACH presentation.
- The student grades were determined using an absolute grading scale and not a "curved" scale.

I. Preparation of eTEACH presentations

In Spring of 2002 the professor converted his lecture notes to PowerPoint slide format but continued to teach the course in the standard format. In Summer 2002, he prepared 40 eTEACH presentations using the PowerPoint slides [13]. A screen shot of a typical presentation is shown in Figure 1. The professor is shown in a video frame lecturing on the material shown in the PowerPoint frame. A table of contents allows the student to navigate the presentation in a coarse-grained manner by selecting presentation sequences with the mouse. The jog buttons on the video player allow the student to jump forward or backward either 10 or 30 seconds in the video. This allows students to conveniently review the same section of the presentation over again. The dynamic links frame has links to other eTEACH presentations or other web content that the author chooses to make known to the viewer. When a link is clicked, eTEACH suspends the video, opens a new browser window with the linked information, and transfers control to the new window. The links feature allows the author to build a threaded list of related topics. For instance, an eTEACH presentation on initial conditions and boundary conditions is given. In a later lesson a differential equation is solved that uses particular boundary conditions. A link to the previous presentation is placed in this presentation so that students can conveniently go back to exactly the point where this concept was previously discussed in detail. This linking backward in the sequence of presentations can be done indefinitely.

II. eTEACH self-assessment exercises

The online eTEACH presentations include self-assessment exercises interspersed throughout the video presentation. One of these is shown in Figure 2. This is a new feature implemented in eTEACH. The self-assessment exercises are not graded or recorded in any way. They are simply a vehicle for students to reflect on what they have just seen and heard and to test themselves on their level of comprehension compared to what is expected. This feature is motivated by the idea that immediate feedback and reinforcement is important to learning. It also adheres to the idea that the assessment is done in a non-threatening way, since no record of the outcomes is made.

The self-assessment exercises have multiple choice questions. Clicking on an answer reveals whether it is the correct answer or an incorrect answer. The exercises also have buttons, that when clicked, transfer the viewer to the point in the eTEACH presentation (or any other web content) that is pertinent to the understanding of the correct answer to the question. Using these features the students can quickly navigate to appropriate material to address any confusion they have about the answers to the questions. The students are not forced to answer the questions in order to continue with the eTEACH presentation. They can skip over them if they wish. Or conversely, they can immediately go to the questions to see if they have mastered the presentation material before watching the presentation, through reading the textbook for instance.

III. In-class quizzes

In Spring 2003, in-class lectures were replaced with eTEACH online presentations and class time was devoted to emphasizing particularly difficult aspects of the lectures and working problems, similar to homework problems. Informal information gathering and student evaluations at the end of the semester indicated that the online lectures were viewed by some students, but that there was too often a tendency for students to skip the eTEACH lecture and come to class unprepared to participate in the discussion and problem-solving activity. In Spring 2004 the previous year's experience was noted and quizzes were given in every class. In-class quizzes were administered on paper, graded by hand and manually entered into the course management system (CMS) grade book. This was a cumbersome and time-consuming practice to do 40 times. Using the CMS online quizzing feature would have facilitated a streamlined approach but the classroom was not equipped with a computer for each student, and this arrangement would not have served the needs of most of the class time anyway. Small portable computer appliances for quiz taking would have been a useful approach to the frequent quizzes.

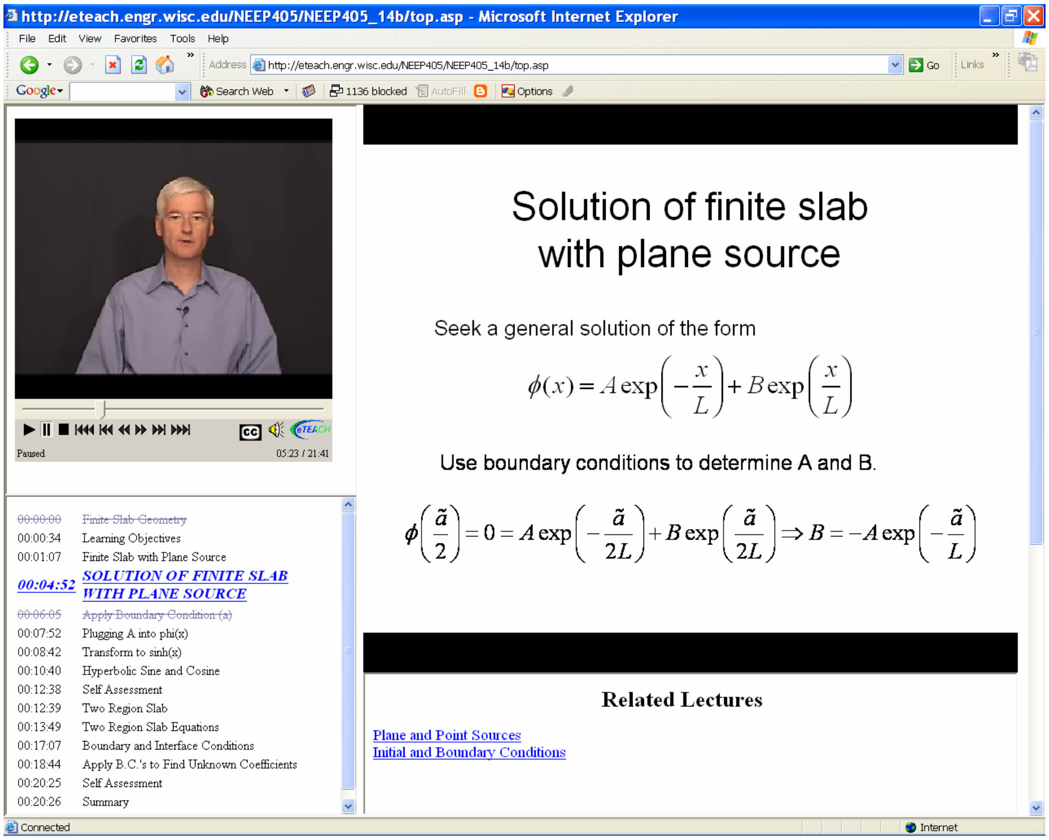

FIGURE 1
ETEACH SCREEN CAPTURE

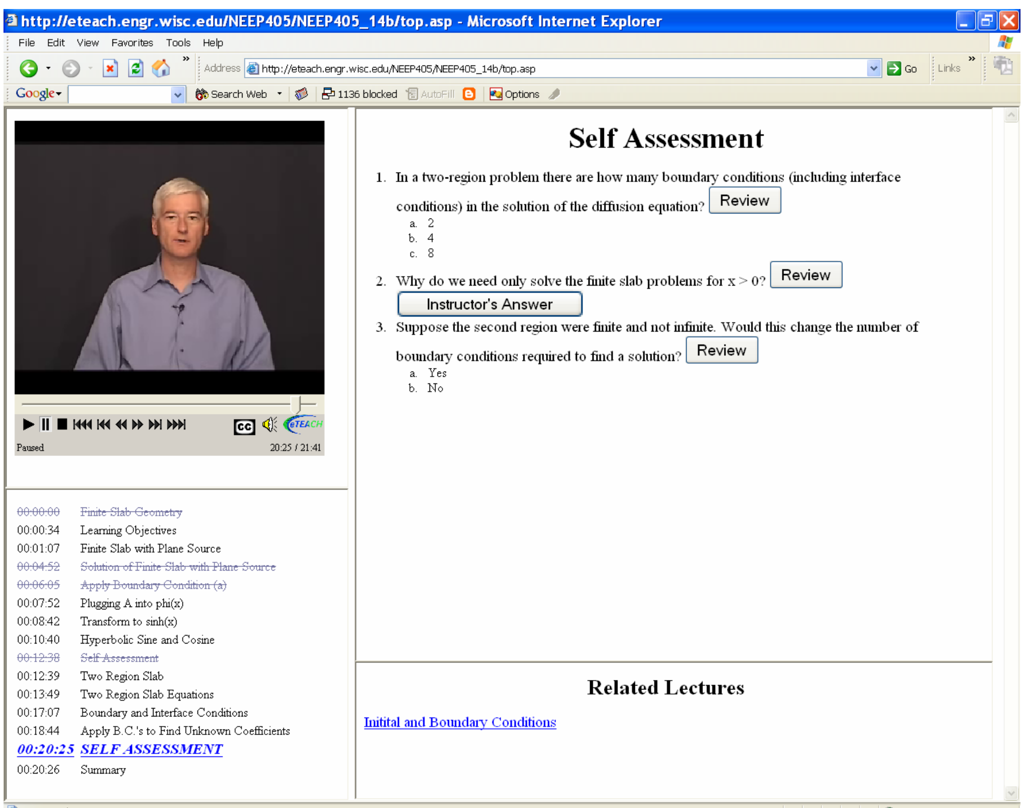

FIGURE 2
SELF-ASSESSMENT SCREEN CAPTURE

The quiz content varied across the 40 quizzes given during the semester. About 50% of the quiz questions were taken from the self-assessment questions found in the eTEACH presentation for that lesson. This was clearly a direct measure of student diligence for watching the presentation. About 30% of the quizzes were more in the nature of workbooks, where students entered results from problems worked in class. And about 20% of the quizzes were questions that were not directly from the self-assessment exercises but which pertained to the content of the eTEACH presentation. Each quiz was counted as 1% of the total course grade so that quizzes also had the effect of improving class attendance.

IV. Absolute Grading Scale

The use of an absolute grading scale was discussed with the students at the beginning of the semester. Students are accustomed to such grading practices in high school, but they generally see "curved" scales in college to account for the potential variability in the difficulty of the few exams that they take. Students accepted the idea of an absolute grading scale because the professor had such a large experience teaching this course and the absolute scale was based upon his past experience. The reason for the absolute grading scale was to allow students to always know where the stood with respect to their final grade. The scale was 90-100=A, 85-90=AB, 75-85=B, 70-75=BC, 60-70=C, 50-60=D and <50=F.

EVALUATION

In order to determine the impact of the revisions made to the nuclear reactor theory course, the instructor hired an independent education researcher from the UW Madison's Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center. The researcher worked with the instructor to enumerate the characteristics of the course and its delivery and developed a 30-question online survey administered about three weeks after the beginning of the semester. The survey collected background information on the students, their confidence levels in various academic areas, their initial impressions regarding the structure of the course, and information about their study practices. A second 42-question online survey was administered approximately two weeks prior to the course's final examination. The second survey collected information similar to the first and was intended to measure changes in opinions about the course as well as changes in study practices. All 32 students enrolled in the course completed both surveys with the incentive of an extra-credit point awarded to their final grade for the completion of each.

I. Overall Impressions of the Course

The vast majority of respondents thought that the underlying problem-solving strategies (97% early in the semester, 100% at the end) and the concepts (97% early in the semester, 97% at the end) they learned in the course would be useful to them in the future. The majority felt that the course covered the right amount of material (69% early in the semester, 64% at the end), while the remainder felt it covered too much. Seventy-five percent reported that the course required more self-discipline than most other courses, and 56% reported that it required more time than most other courses (47% reported somewhat more and 9% reported much more). Thirty-eight percent reported that it required about the same amount of time as other courses, and 6% reported that it required somewhat less time than others.

II. eTEACH Online Presentations

Students were surveyed extensively about the online aspects of the course, including the use of eTEACH to deliver all of the course lectures. According to the survey responses, about two thirds (66%) watched all of the lectures. A total of 78% reported watching at least three-quarters of the available lectures. Only three students (9%) reported watching none of the lectures. All of the students who reported watching the lectures reported that they viewed them on the day prior or just prior to the class meeting for which they were relevant. At the beginning of the semester, 65% reported that their dorm or home was their preferred location to view the lectures. At that time, 23% would have rather viewed a live lecture in person. By the end of the semester, this proportion had increased to 30%, while the number preferring to watch the lectures at home remained stable.

Further, nearly every student who watched the lectures capitalized on the eTEACH technology to view material in ways that are not possible with live lectures. At the beginning of the semester, 75% (24 respondents) reported stopping the lectures to take notes or check other resources. At the end of the semester, four respondents (12%) reported stopping the lectures more frequently than at the beginning of the semester, while 58% reported no difference. The remainder reported stopping them less frequently. Just over half of the respondents (53%) reported they would go back over part of a lecture in the same sitting. Sixty-seven percent of these reported doing so more often at the end of the semester than at the beginning, while 33% reported doing so less often. Sixty-three percent reported that watching the lectures online was at least somewhat more convenient that attending lectures in a more traditional course, while 27% reported that the two formats were equally convenient. When asked if it was easier to take notes to understand the material when viewing lectures on eTEACH than it would have been attending the same lecture live, 59% agreed either strongly (31%) or somewhat (28%).

The respondents explained a number of benefits they derived from watching the lectures on eTEACH rather than in person. Several of these were common to many of the respondents. One widely appreciated benefit was the online availability of lecture PowerPoint slides. The slides allowed them to concentrate on the topics of the lecture, rather than focusing on taking notes or recording complex mathematical formulas. Students additionally valued the ability to review topics until they understood the material well. Pausing and rewinding the lecture allowed them to comfortably assimilate information before moving to the next topic. Conversely, some appreciated the ability to skip material with which they were already familiar.

The most commonly reported disadvantage of the course's lecture delivery was the difficulty in asking questions. One respondent appreciated the promptness of responses to e-mailed questions, but otherwise agreed with others who missed the ability to ask live questions as they arose. Other disadvantages were much less commonly shared by the respondents, but included the lack of ambient formality when viewing the online lectures (as compared to the formality of a lecture hall or classroom setting), the abundance of distractions when viewing lectures online, and the difficulty of remembering questions or problems until the class met to discuss the materials.

The students were asked about the effect that placing the lectures online through eTEACH had upon their learning both at the beginning and at the end of the semester. Table I shows the change in how respondents assessed this effect over time. At the end of the semester, the respondents were slightly less likely to endorse the positive effects of the online lectures than at the beginning. Among those who reported no effect or a negative effect, most commented that they did not watch the lectures. Those who reported a negative effect generally attributed it to their own difficulties with self-discipline. This result is consistent with an earlier evaluation of eTEACH [11].

The end-of-the-semester survey asked if the lectures for all engineering courses should be presented in the eTEACH format, and 64% percent disagreed (39%) or strongly disagreed (24%). The reasons for this were varied. Most of those who did not think all course lectures should be delivered this way agreed that students would not consistently spend the time necessary to master the material. Many also felt that in-person interaction was important for many courses, especially those that cover very detailed or complicated topics. Several, however, felt that making the lectures available on eTEACH in addition to in-person lectures would provide students with a good supplementary resource, allowing them to review or preview lectures at their convenience. Finally, several felt that many courses are simply presented more appropriately in a traditional lecture format. Among those who liked the idea of presenting all course lectures in this format, most cited the general benefits discussed earlier. In a subsequent discussion in May 2004 between nuclear engineering students and the department's Industrial Advisory Board, it was learned that students were afraid that all courses would move in this direction as a cost saving measure by the Dean. They foresaw a future where there were no classes and all coursework was online. They were strongly opposed to this scenario.

At the end of the semester, the students were asked to rank six activities conducted in the nuclear reactor theory course in terms of the degree to which they assisted in illustrating the underlying concepts in the course. The rankings for each of the six were weighted and averaged to determine the overall average ranking for the respondents.

From most helpful to least helpful, they are: lectures, homework, class discussion, lecture slides, reading the textbook, and quizzes. When asked which of these activities

TABLE I
STUDENT SELF ASSESSMENT OF EFFECT OF ETEACH PRESENTATIONS ON LEARNING

Student Response	Beginning of Semester(%)	End of Semester(%)
Very negative	3	0
Somewhat negative	10	15
None	13	15
Somewhat positive	39	39
Very positive	35	31

were *truly* not helpful, a fair number (33%) reported that reading the text was not helpful. An additional 15% reported that the quizzes were not helpful. Few reported that the homework (9%), slides (6%), lectures (3%) or class discussions (3%) were truly not helpful for mastering the underlying concepts of the course. Table II shows respondents' assessments at the end of the semester of the importance of other specific course characteristics to their learning.

III. In-class Quizzes and eTEACH Self-assessments

The administration of daily quizzes and homework assignments had a significant impact on the respondents' experiences. The majority of respondents felt that preparations for the daily quizzes better prepared them to complete the homework sets (38% agreed and 25% strongly agreed at the beginning of the semester and 36% agreed and 24% strongly agreed at the end). At the beginning of the semester, 87% felt that the quizzes were a fair way of assessing their learning (59% agreed and 28% strongly agreed), while only 69% felt the same way at the end of the semester (42% agreed and 27% strongly agreed). Some of this decline might be attributed to the realization that the questions often came directly from the self-assessments in the lectures. Some students reported doing enough work to complete the self-assessment, but not enough to gain true mastery of the material. Others pointed out that the quizzes were open-book, and thus may not have truly reflected learning gains. Those who felt the quizzes were a good measure of learning reported that they covered the material presented well and that they showed whether the students had done at least the minimum amount of work necessary to learn the material. Finally, the majority of respondents (85% at the beginning of the semester and 79% at the end) also felt that the homework sets were a fair way to assess their learning gains. They most commonly expressed the sentiment that the homework sets were comprehensive and allowed them to demonstrate their ability to apply course contents in various circumstances.

IV. Absolute Grading Scale

Finally, most students were comfortable knowing that their grades were being determined on an absolute scale, rather than on a curve. Seventy-five percent did not have any problem with this (56% agreed that they were comfortable and 19% strongly agreed). Most shared the sentiment that such an arrangement should not be applied universally to engineering

TABLE II
STUDENT SELF ASSESSMENT OF IMPORTANCE OF COURSE CHARACTERISTICS TO THEIR LEARNING

	Critical to learning		Helped a good deal		Helped somewhat		Not worth the time	
	Begin	End	Begin	End	Begin	End	Begin	End
Reviewing the videotaped intros to each section	19%	13%	22%	23%	25%	26%	34%	39%
Hearing the professor's videotaped lectures	34%	32%	34%	29%	22%	29%	9%	10%
Seeing the professor while he was lecturing	19%	28%	19%	31%	44%	25%	19%	16%
Viewing the PowerPoint slides that went with lectures	69%	56%	28%	34%	0%	6%	3%	3%
Reading the course text	13%	28%	28%	25%	47%	19%	13%	28%
Going through example problems on the syllabus	23%	19%	23%	38%	29%	31%	26%	13%
The frequency of the quizzes	53%	34%	25%	38%	22%	19%	0%	9%
The length of the quizzes	38%	31%	47%	41%	16%	22%	0%	6%
The types of questions covered on the quizzes	47%	38%	44%	47%	9%	6%	0%	9%
Working on or discussing engineering problems with other students	48%	63%	26%	19%	19%	16%	6%	3%
Completing the homework assignments	50%	59%	41%	28%	9%	9%	0%	3%
Having the professor available to discuss coursework during scheduled class times	47%	69%	28%	25%	22%	6%	3%	0%

courses. There was consensus that this requires significant work on the part of the faculty member and would not be appropriate for many types of courses, even if the instructor is highly experienced.

CONCLUSIONS

The four reforms made to the nuclear reactor theory course received a generally favorable response from the students. However, the responses were mixed. In particular, the online eTEACH presentations were not enthusiastically embraced in comparison to the experience with an earlier study. The 40 quizzes received a mixed response as well compared to an earlier reform [11]. One possible explanation for the difference is the relentless nature of the online lectures and quizzes occurring three times per week, in comparison to once per week in the earlier reform study. Furthermore, the comments by the students regarding their fear that the College of Engineering will attempt to offer all courses online and eliminate the conventional classroom perhaps added to their apprehension. There was no explicit mention of this to the students, but in planning teaching productivity and cost savings, these topics are discussed by the Dean. The students who were interviewed "put two and two together" and drew this conclusion.

The performance of students in the reformed class was nearly a half grade better than the performance of students in previous conventional classes. The statistical significance of this difference awaits further accumulation of data on performance under the reformed format.

ACKNOWLEDGMENT

This research was supported in part by the National Science Foundation as part of the Education, Outreach and Training Partnership for Advanced Computational Infrastructure (EOT-PACI), the University of Wisconsin-Madison College of Engineering and the UW Graduate School.

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