A look at an active learning strategies for deeper understanding: a case study in Mechanics of Materials

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Abstract
Active learning encompasses anything students might be called on to do in class besides watching and listening to an instructor and taking notes (Felder & Brent, 2016). The purpose of this study was to incorporate active learning strategies into Mechanics of Materials, a core engineering course, in order to provide a more meaningful and deeper learning experience for students.
The active learning strategies incorporated in this case study include individual and group problem-solving, peer interaction, and live polling with immediate feedback to both the instructor and the learners. A few problem-based instructional activities were piloted in the Fall Semester of 2015 with full-scale implementation in the Spring Semester of 2016. After a successful implementation with increased student scores and positive feedback, the course was further enhanced and converted into a flipped model in the Spring Semester of 2017. The flipped model allows for a much greater amount of active learning during class time. Positive results, both statistically and anecdotally, have warranted to continued use of the active learning strategies developed within this course.

1-Introduction

A search of active learning on the Internet returns hits on theory, definitions of, strategies, examples, and activities. In a broad sense, this is a great place for any instructor who is a novice to active learning to begin when determining what active learning is and which strategies may work. Active learning, as defined by Felder and Brent, is a teaching approach that encompasses anything students might be called on to do in class besides watching and listening to an instructor and taking notes (Felder & Brent, 2016). Many strategies have been developed to promote active learning in the classroom. A few such strategies include sketches of form, critiques of various samples, brainstorming activities, and determining calculation errors (Felder & Brent, 2016). Additionally, student-to-student collaboration or peer instruction (PI) engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Unlike the common practice of asking informal questions during lecture, which typically engages only a few highly motivated students, the more structured questioning process of PI involves every student in the class (Crouch & Mazur, 2001). Even with this enhanced student involvement, however, many instructors in higher education are reluctant to adopt active learning strategies.

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Dan Berrett (2012) quotes Michael S. Palmer as stating, “The way STEM disciplines are traditionally taught makes them particularly ripe for change, because of their “long tradition of very didactic teaching, which involved disseminating content.” The traditional lecture classroom model focuses the attention of students solely on the instructor (instructor-centered instruction), in a relatively quiet and controlled environment. Many instructors fear that they may lose control of the class and/or classroom management issues might arise when students are given the ability to collaborate and discuss with a less rigid structure, where students have more control over their own (student-centered) learning environment (Felder & Brent, 2016; Pedersen & Liu, 2003; Snell & Steinert, 1999).

For those instructors who do adopt an active learning component in their courses, the instructor role is oftentimes transformed from that of the sole source of information to a learning facilitator or coach, though the description of the facilitation role may differ widely based on the specific learning activities (Felder & Brent, 2016; Pedersen & Liu, 2003; Snell & Steinert, 1999). The role of facilitator is frequently seen in the flipped classroom model where there is pre-work, a short mini lesson prior to class giving students exposure to material in the form of a short video or online module, then in-class session that involves students solving conceptual questions using active learning strategies (McLean, 2017). The “flipped classroom” or “flipping” as it is often referred to (Barrett, 2012), provides the student with the flexibility to view the pre-work on their own schedule and at their own pace. Instructors can create these mini lessons sitting in their office using a webcam and a computer or refer students to already created lessons from various open education resources. Either way the students receive their first look at the course material that pertains to a student learning objective prior to coming to class, thus giving the instructor more valuable time during the class period to use active learning strategies like having students interact with one another by peer instruction (Crouch & Mazur, 2001), think-pair-share (McLean, 2017) or problem based learning in most STEM courses. While the active learning is happening during the class period, the instructor can circulate around the room observing, asking thought provoking questions, responding to those questions that their peers are unable to answer and correcting any misconceptions that students may have. The goal is to have students use the in-class session to increase their skills and deepen their knowledge and understanding of the course content through practice (Felder & Brent, 2016).

Confucius once said, “I hear and I forget. I see and I remember. I do and I understand.” (Quotes, 2017). In this article, we will discuss one approach to assisting students in a Mechanics of Materials class to better grasp the concepts and to do so in deeper and more meaningful way. The study involving engineering students at Missouri University of Science and Technology in a Mechanics of Materials course assessed the active learning strategies used to better engage students in discussion, peer instruction and problem solving during class. One strategy in the study used multiple choice quizzing during class with the goal of helping students to learn by practicing difficult problem-solving while the instructor and peers were available for assistance.

In addition to having instructor and peer support during the problem-solving process, students also benefit from answering not just correctly, but also by answering incorrectly - especially when given the correct answer soon afterward. That is, *guessing wrongly* increases a person's likelihood of nailing that question, or a related one, on a later test (Carey, 2014).

2-Active learning technique using in-class practice problems

The study involves practicing sample problems in a class session and collecting students answers using Kahoot which is a web based polling system. Once in class, the instructor spent a short amount of time to expand upon the student learning objectives addressed in the videos and in demonstration of examples so that students more deeply understood how to apply the concepts. The rest of class was then structured toward active learning, a teaching approach that encompasses anything students might be called on to do in class besides watching and listening to an instructor and taking notes (Felder and Brent, 2016). In this particular course, the active learning involved student problem-solving practice, both independently and in small groups.

The instructor also facilitated student learning by posting a scenario/problem on the board for students to solve using the concept covered during the first portion of the class. The students were given a few minutes to solve the problem independently before they were allowed to work in small groups to compare their answers with their peers. Real interaction and discussion was observed during this collaborative learning time. The students discussed, taught, and explained to one another how the problem was to be solved (Libre, 2017).

Video and lecture content is enhanced using multiple active learning strategies in class. The collection of active learning strategies leads to greater student success. As shown in Figure 1, after the brief self-assessment and collaborative learning time, students were then quizzed in a low-stakes formative assessment using Kahoot, a free, electronic personal response (polling) system. Personal response systems are helpful in the active learning process because they render immediate feedback to instructors and students, as well as the ability to provide retrieval practice, test conceptual understanding, and identify common student misconceptions (Felder and Brent, 2016). Additionally, Kahoot facilitates simple attendance-taking in large classes as well as data collection for tailoring subsequent "just in time" videos and class instruction prior to high-stakes, summative assessments.

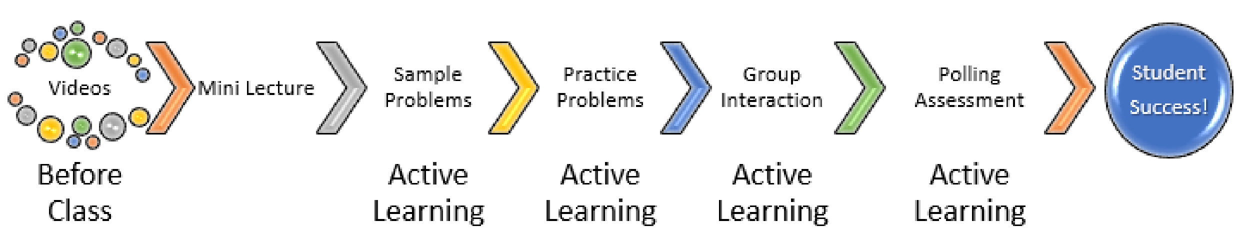


Figure 1- Active learning technique using in-class practice problems

Using this type of software served several pedagogically effective purposes: first, it provided immediate feedback to students while keeping track of individual performance; second, the software provided the instructor with instant feedback on how well the class understood previous concepts as well as new material; third, it provided digital data on which questions were more difficult for students to grasp so the instructor could focus additional learning events on common misconceptions tailored to specific learners and/or class sections; and fourth, this method of self-testing helped students to improve their learning because each test of knowledge served as an additional study session, which leads to improved retention as described by Roediger & Karpicke's *testing effect* (Carey, 2014). An added benefit in using this software was to track who was present in class and actively participating, without wasting valuable class time.

This instructional method provides a great distinction from techniques used decades ago. In Fritschner's article, she quotes a study conducted in 1976 by Karp and Yoels, where they investigated the roles of students in the college classroom and reasoned that the educational system teaches students to passively view instructors as "experts" who impart "truth," (Fritschner, 2000). Since that time, more research has been conducted and continues to show that active learning strategies produce better understanding of course content (Crouch & Mazur, 2001; Klymkowsky, 2014 Lucas, et. al., 2013). Such research provides the basis for increased adoption of active learning strategies in higher education.

3-Research methodology

The described active learning technique has been incorporated as a part of the CE2210 - Mechanics of Materials class for three semesters, beginning in the Spring semester of 2016 and continuing through Spring of 2017. Mechanics of Materials is a core engineering course that is offered to students from various engineering disciplines including: Civil Engineering, Mechanical Engineering, Aerospace Engineering, Petroleum Engineering, Nuclear Engineering, Metallurgical Engineering, Architectural Engineering, Geological Engineering, Environmental Engineering, and Engineering Management. Enrolled students are mostly sophomores and juniors who have passed Statics and Calculus III as prerequisites. The number of enrolled students in each semester is summarized in Table 1.

In the pilot semester, e.g. Fall 2015, the active learning technique was tested as a prototype with just five practice problems, mostly offered in the last quarter of the sixteen week course. Following the successful pilot of the technique, more in-class practice problems were offered in subsequent semesters. Table 1 shows the number of in-class practice problems offered to students in each semester during the research period. In Spring-2017, the curriculum was redesigned to flip the class, placing a greater emphasis on the problem-solving active learning strategies. In the flipped approach to teaching, short video lectures are viewed by students at home before the class session, while in-class time focuses on more difficult skills which require greater practice, student-to-student collaboration, and discussions. In this pedagogical model, the in-class practice problems are implemented as a main component of the course curriculum to facilitate active learning during the class time. In total, 45 questions were offered to students as practice problems throughout the spring of 2017; averaging 1.8 questions per class session.

Table 1- Enrollment and course data during the research period

Semester	Number of practice problems	Maximum score of practice problems	Number of students
Spring 2016	33	50	140
Fall 2016	36	50	135
Spring 2017	45	120	353

The number of in-class practice problems has increased during each semester since implementation of the strategy. The majority of this increase happened in Spring 2017, when the classroom environment was flipped in order to provide more opportunity for student-centered, active learning.

The in-class practice problems were administered as low-stakes formative assessments. Such assessments can be used by instructors during the learning process in order to reinforce student learning and improve achievement of student learning objectives. Formative assessment typically involves gathering feedback that can be used for improvement in the ongoing teaching and learning context in contrast to summative assessments, which seek to determine the measure of a student's learning. As such, formative assessments usually have lower grades compared to summative assessments that form the majority of the course grade. Based on the author's experience, using graded formative assessments consisting of relatively low point values, often even as bonus points, motivates students to get involved in the class activities. Additionally, according to Felder and Brent, providing a pause in the lecture in order to provide time for students to work individually or in small groups on a problem related to the lecture content enhances active learning and prevents cognitive overload by preventing a nonstop flow of information (Felder and Brent, 2016). In our model, 50 bonus points were considered for all in-class practice problems, which accounts for 5% of the total course grade. It was found that even 5% of total score provides motivation for students to participate. The student participation rate was greater than 98% during the research period. In the Spring 2017, the semester in which the in-class practice problem adopted as a main component of the flipped class, the total score for in-class practice problems was increased to 120 points, 50 as mandatory points and 70 as bonus points. It is worth mentioning that the graded components of the course include homework, quizzes, four midterm exams and the final, cumulative exam, which all accumulate to 1000 points in total. In addition, students had a chance to obtain bonus points by participating in different activities including answering questions that were asked during class sessions, doing supplementary homework, and other optional practice work. The bonus points were capped at 70 points in all semesters, no matter what type of extra work a student may have chosen to attempt.

Two scoring systems were used to grade students responses; the Boolean method and the Fuzzy method. In the Boolean method, the students with the correct answer received 100% of the question point(s) and students with incorrect answers received zero point. In the Fuzzy method, points were calculated based on speed of answer and each question's time limit using the following equation:

$$Score = \left(1 - \frac{Response\ Time}{2 \times\ Question\ Timer}\right) \times Question\ Point\ Value$$

In this scoring system all correct answers received 100% of question points if students responded correctly in under 0.5 seconds; the minimum point value for a correct answer was 50% of the total question points and wrong answers got zero points.

Results and discussion

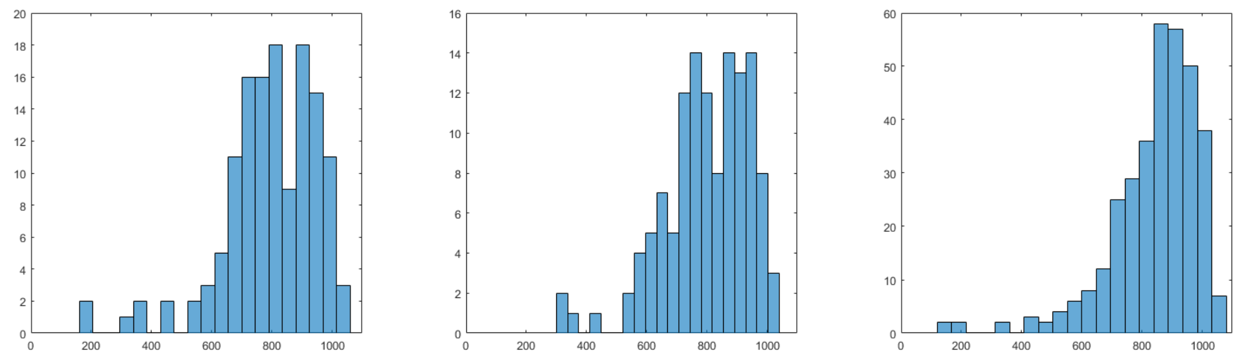
During the research period, academic learning performance was compared to determine the learning impact on students when the in-class practice problems were implemented. Students' knowledge was assessed by weekly assignments and four midterm exams during the semester. The final examination was conducted at the end of semester (week 16). The final exam questions were pulled from a database of standard questions that were used several times before the research period. To prevent students from passing-on exams from one year to the next, students were not allowed to keep their final exams. The performance of students in the final exam before the research period is considered as the reference; performance of students during the research period is compared with the reference to evaluate impact of the active learning on students. Table 2 shows the performance of students in the final exam during the research period compared to the reference baseline. A grading scale of 0 to 100 was used for the exams. The class average of Spring 2016 was 73.8; The average of student's performance for the same exams before the research was 74.5. The difference is less than 1% which shows there is not a significant difference between the test group and reference group in the first semester of implementing the active learning technique. However, in Fall 2016 that was the second semester of applying the active learning technique, the test group outperformed the reference group by 2.5%. The improvement in the student's performance was higher in the Spring 2017 semester when the in-class practice problems were incorporated as a main component in the course curriculum. The difference between the test group and reference group was 4.8% in the third semester of applying the proposed active learning strategy. Such an improvement could be attributed to implementing the active learning technique in the course curriculum which positively impacted student learning.

Table 2- Academic performance of students during the research period

Semester	Reference	Test	Difference
Spring 2017	71.5	76.3	4.8
Fall 2016	67.7	70.2	2.5
Spring 2016	74.5	73.8	-0.7

Student academic performance increased 4.8% after the full implementation of the problem-solving active learning strategy in Spring 2017, which could be attributed to the implementation of the strategy itself.

Student's engagement in the class activities not only resulted in a better performance in the final exam, but also reflected in other assessment areas like homework assignments and midterm exams. Figure 2 demonstrates the course grade distribution for the investigated research period. Assessment areas of the course grade include homework, quizzes, and four midterm exams, as mentioned before. The implementation of the active learning technique has shifted the histogram graph to the right side confirming that the proposed technique not only improved the performance of students in the final exam but also in the other assessments areas.



Spring 2016 *Fall 2016* *Spring 2017*

Figure 2- Histogram of course grade distribution during the research period

Overall students performance in the course is strongly related to their performance in the in-class practice problems during the semester. Such a correlation between in-class practice scores and the course score are shown in the Figure 3 for Spring 2017. The same trend was observed in the other studied semester. Such a strong correlation proves that those students who engage more in the class activities benefited more and learned the concepts better.

Both Boolean and Fuzzy scoring systems were considered in the calculation of scores of in-class practice problems. No significant difference were observed between two scoring systems described before. The Boolean system seems to be more practical because of its simplicity compared to the Fuzzy scoring system. However, this topic needs more study prior to final conclusion.

Monitoring students performance throughout a semester by observing their engagement in active learning activities could be used for developing an automated monitoring system for detecting students who are in danger of failing or need special help to be successful in the course. Sadati and Libre (2017) used the data collected during the active learning experiments to develop an early alert system to identify students in academic trouble before failure.

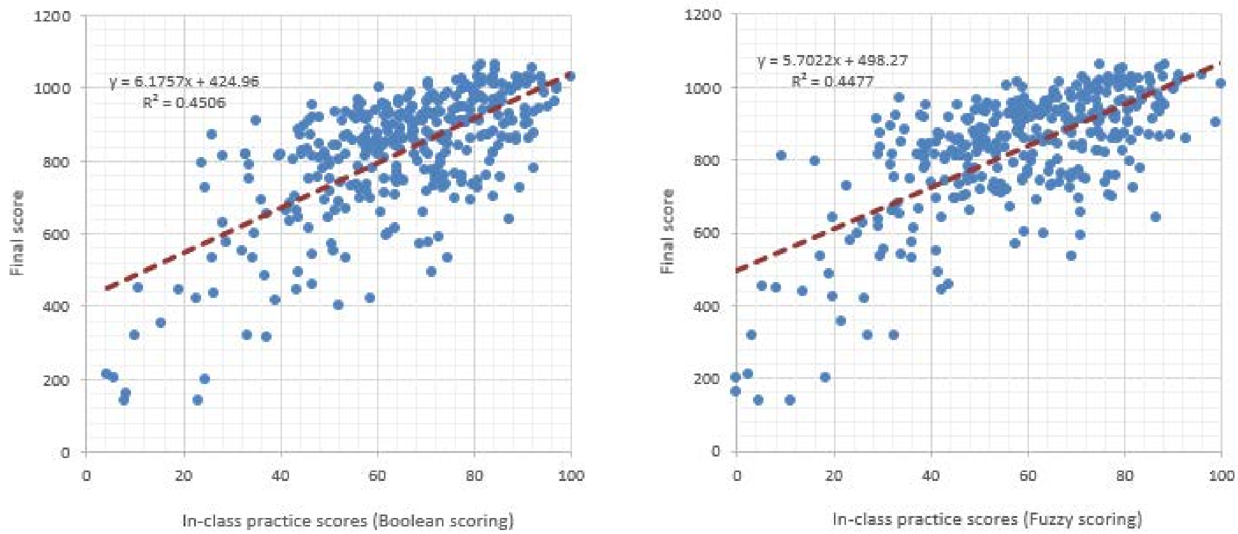


Figure 3- relation between the in-class practice problems collected during the semester and the course score determined at the end of semester

Student's feedback: In addition to the performance measurement two surveys were constructed to all students of the classes during and at the end of each semester. The mid semester survey was administered by an independent entity in Spring and Fall of 2016 . To avoid any bias, no students information was shared with the instructor. The final survey was done on the very last week of all semesters by the University Committee on Effective Teaching in a blind way. The instructor was able to see the results only after the course concluded and the final grade had been submitted.

In the mid-semester survey, there were two questions related to the applied active learning technique. The first question was about how the in-class practice problems, class discussions and related activities has facilitated student-to-students interaction in class. The second question was about what is students opinion about integration of the in-class practice problems with the Mechanics of Materials course. Figure 4 summarizes students feedback for two questions related to the implementation of in-class practice problems in the course. The students see the impact of the active learning as a positive factor on their learning. The results presented in Figure 3 support this statement. Student's feedback was mostly positive for both questions. Majority of students replied Excellent or Good for these two questions. It is worth noting that the student's opinion were more positive on the 2nd semester compared to the first semester of the research period.

The change in the students perception on how effective is the active learning technique on their learning shifted upward toward excellent side of the graph as shown in Figure 4. In the 2nd test semester none of the students voted fair or poor for the asked questions related to active learning. It could be attributed to the improvement on implementing the proposed active learning technique over time as well as better adoption of this technique by the instructor and students.

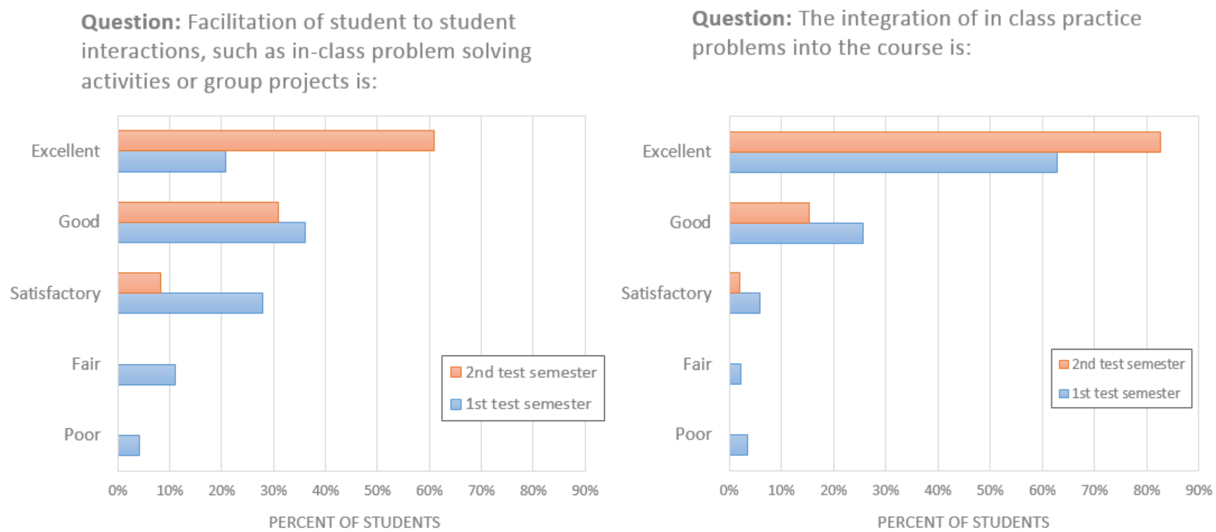


Figure 4- Students response to the questions related to the effectiveness of the proposed in-class practice problems

The improved student's feeling was also reflected in the overall course evaluation by the end of semester. As shown in Figure 5, an improving pattern can be seen in the overall teaching effectiveness. This shows the active learning technique not only improved the students' overall performance, but also their perception on how their engagement in class activities are beneficial for them. Student performance and impressions of teaching effectiveness improved as the active learning strategy was used more frequently in the class.

Figure 5- Overall course effectiveness in Fall and Spring 2016

Finally from the attitudinal survey, as a whole, the majority of students seem to have benefitted from the active learning technique conducted during the semester. Comments like this were repeated on the student's feedback:

> *"The in class problems are the best part of the class"*
>
> *"In class problems keeps us very involved and provides us with instant feedback on our understanding of the topics."*
>
> *"In-class quizzes-keep you focused in class because you want to understand how to solve the problem for bonus points."*
>
> *"In-class problems has been the best in terms of in class learning. It sticks with me better than just watching examples and not practicing till I start the homework."*
>
> *"The in-class quizzes are great because they allow you to solve a problem and get the correct answer so you then have a basis on how to approach the hw."*

Conclusion and future work

The research presented and discussed here reveals that using active learning strategies of discussion, peer instruction and problem-solving in a flipped classroom model provides students with an essential and engaging learning process that provides a hands on approach, which results in a deeper learning of the material. Even though the emphases was not on the technology and more on the strategies used, the flipped classroom model would not be possible without the use of technology. The student feedback and the exam results indicates that the use of active learning strategies enhanced by the use of technology in and out of the classroom can be used to engage students and keep them focused in the learning process.

Considering the significant improvement on students learning as well as positive feedback received from students it can be determined that the implementation of the proposed active learning can be effectively used to engage students in their learning process. Also, it reveals that students not only like the implementation of active learning in their coursework, but also perceive the value of such technique on their learning.

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Nicolas Ali Libre, PhD, is an assistant teaching professor of Civil Engineering at Missouri University of Science and Technology. He received his BS (2001), MS (2003) and PhD (2009) in civil engineering with emphasis in structural engineering, from University of Tehran, Iran. His research interests and experiences are in the field of computational mechanics, cement-based composite materials and teaching innovations.

Given his multidisciplinary background, he was appointed as the director of research in the Construction Materials Institute (2011-2013) at the University of Tehran. In April 2013 he relocated to the US and joined Missouri S&T as a visiting scholar and served as an assistant teaching professor since 2015. In that capacity, he had the opportunity of leading several scientific and industrial research projects and mentoring graduate and undergraduate students. Dr. Libre is manager of Materials Testing lab at Missouri S&T, teaches mechanics of materials and develops digital educational resources for the engineering mechanics courses. Over the span of his career, Dr. Libre authored and co-authored 3 chapter books, 17 peer-reviewed journal articles and over 60 conference papers. He has advised and co-advised 7 graduate students and mentored over 30 undergraduate students. He has collaborated with scholars from several countries, including Iran, China, Slovenia, Canada, and the US. He also served as a reviewer for 6 journals and a committee member of 5 conferences. He is the recipient of Excellence in Teaching Award from the National Society of Leadership and Success and Joseph H Senne Jr. Academy of Civil Engineering Faculty Teaching and Service Achievement Award.

Jeffrey W. Jennings is employed by Missouri University of Science and Technology as an instructional designer. He holds a B.S. in Middle Childhood Education (science and mathematics) from Georgia State University and a M.Ed. in Educational Leadership from Trident University International. Currently, Jennings is a doctoral student at the University of Missouri – St. Louis. He has been in the field of education off and on since 1996 as a middle school teacher and served as a Functional Course Manager in his last duty assignment prior to retiring from the United States Army in 2011.

As an instructional designer in Educational Technology, Jennings assists instructors in redesigning their courses using both best practices and sound pedagogical strategies to an online or blended format. Jennings is developing an expertise in course alignment through departmental program alignment and believes that a good foundation in course design and alignment closes the gaps between course goals, student learning objectives and the assessment of those objectives that leads to a more engaging course for students. Jennings also enjoys the outdoor experiences with family and being a soccer coach.

S. Amy Skyles is employed by Missouri University of Science and Technology (Missouri S&T) as an instructional designer and is also an instructor for the Canvas Network. She holds a BS in Biological Sciences from Missouri S&T and a Master's of Education from Drury University. Skyles is also certified as an online educator by the University of Missouri, Columbia (Mizzou Online). Currently, Skyles is a doctoral student at the University of Missouri St. Louis. She has been in the field of education since 2003 as a junior high school teacher, adjunct instructor for multiple institutions, and instructional designer. Skyles has developed an expertise in laboratory redesign practices using best pedagogical methodologies. Skyles is recognized as the "go-to" person on the S&T campus for learning about instructional design of laboratory courses and experiential learning activities, including DELTA Labs, which strive for the goal of Delivering Experiential Labs to All.

Skyles has a passion for learning and would consider herself a lifelong learner who is perpetually trying to discover new things and new ways of doing the things that she has already made a part of her life. Teaching and learning are both very enjoyable for Skyles and she is passionately believes that using active learning strategies as well as flipped, blended and online learning models should be considered as a part of the standard way of teaching instead of as new or emerging types of instruction. At home in Rolla, Missouri, Skyles enjoys spending time with her husband and two children; oftentimes coaching, spectating, or playing on the baseball or softball field.