Restructuring a Modeling Dynamics Course with Absorb-Do-Connect Learning Units

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Introduction

The authors experimented with the teaching pedagogy used in a graduate level mechanical engineering course. Modeling Dynamics of Mechanical Systems (Modeling Dynamics) is a 700-level cross-listed course offered to both graduate-level and senior undergraduate students. Most enrolled students are Mechanical Engineering undergraduates who take the course as an advanced elective, with the remainder coming from Mechanical Engineering or Bioengineering graduate programs. The course, which has reached capacity enrollment (30+ students) for multiple years, is taught in a computer laboratory with one student per computer. The instructor is accompanied by one graduate teaching assistant (GTA) during active learning class sessions. The overall learning objective of the course is to teach students to use modern computer simulation software to solve engineering problems in a virtual space. Students program simulated models to represent realistic dynamic behaviors of mechanical systems both visually and mathematically.

Two separate simulation programs are taught in this course: 1) MSC Adams and 2) MATLAB-Simulink. MSC Adams (Automatic Dynamic Analysis of Mechanical Systems) is a multibody dynamics software intended for simulations of complex mechanical systems (https://www.mscsoftware.com/product/adams). Adams features a graphical user interface similar to most computer-aided design (CAD) programs. Users identify model parameters in the CAD interface, and the resulting governing equations are automatically evaluated by the software. MATLAB is a matrix-based programming language that is structured similar to C/C++ coding. Users directly code all program files and functions to develop mathematical models of real-life systems based on the governing equations of motion. Simulink is a graphical programming language tool used for modeling, simulating, and analyzing dynamical systems within MATLAB and resembles National Instruments LabVIEW. Simulink and MATLAB can be used in parallel to rapidly simulate and analyze several iterations of complex models.

Methods

Modeling Dynamics has been taught utilizing in-class active learning activities for several previous semesters based on overwhelming evidence of improvements in student learning (Felder, 2000; Felder, 2004; Freeman, 2014). Class sessions consisted of brief lectures on the modeling tools followed by active learning simulation exercises. Students worked alone but were encouraged to work in casual self-formed groups on these exercises while the instructor and GTA were available in the room to assist when needed. Homework simulation problems were completed individually outside of class. For the Fall 2018 semester, the instructor wished to elevate student learning by fostering a deeper learning in the vast applications of the modeling tools. A new instructional framework was introduced to intentionally connect course content with real-life scenarios with the goal of increasing student motivation. The new framework was based on the Absorb-Do-Connect model (Horton, 2011).

In our application of the Absorb-Do-Connect active learning model, we divided each course topic into three learning phases. The first phase, Absorb, incorporates the lower two levels of Bloom's taxonomy, remember and understand (Bloom, 1956). "Absorb" activities, which are completed individually before attending class, aim to activate prior knowledge and develop new foundational knowledge for the current course topic. Students are provided a problem statement and an example program solution, which they are expected to review and comprehend. The "Absorb" content is a simpler version of the material that will be covered during the in-class active "Do" learning exercises. While the "Absorb" activities sound passive, the student should be mentally active as they perceive, process, consolidate, and understand the information presented. The in-class active learning "Do" phase incorporate Bloom's levels three and four, apply and analyze. Students work in groups to master and expand upon the fundamental concepts gained in the "Absorb" activities done prior to coming to class. The primary goal is to encourage student groups to gain practice with the material by attempting the exercise, while the instructor and GTA are available to provide "just in time" feedback to enhance the learning process. Following the completion of the "Do" activities, the "Connect" phase begins during class and is completed individually outside of class. Students are elevated to Bloom's highest levels of learning, evaluate and create, by expanding upon the concepts from the active learning "Do" exercises and applying them to more complex real-life scenarios.

The following is an example of the first Absorb-Do-Connect learning unit from Modeling Dynamics in the Fall 2018 semester which focuses on one-dimensional particle dynamics:

> **Topic #1: One-dimensional particle motion under gravitational force only**
> **Absorb:** Students receive an electronic copy of the problem statement along with a complete derivation of the governing differential equations for the simplified base model. A MATLAB-Simulink program file is also provided with all necessary code completed to solve the base model. Students are expected to review and "absorb" the material prior to attending class. A short, graded, multiple choice online quiz is also to be completed before class to check understanding of the base model.
> **Do:** During class, the instructor overviews the new problem statement, which is an expansion of the base model. In this example, air friction of the particle is added to the model as a linear function of velocity. Students work in groups during class to derive the appropriate equation of motion and initial parameters for the system. Individually, students modify the MATLAB-Simulink program from the "Absorb" activity to solve the more complex "Do" model. Students submit screenshots of their simulated results for grading via an electronic worksheet. A second online quiz is also graded.
> **Connect:** The instructor provides an in-class introduction to the further expanded problem statement. In this instance, air friction of the particle is now modeled as a nonlinear function of velocity. A brief active learning session discusses considerations for deriving the equation of motion, defining initial parameters, and other factors for the more complex model. As homework, students work individually to modify their "Do" simulation to analyze the dynamics of this realistic system. For grading, students submit their MATLAB-Simulink program file, a second worksheet with updated screenshots of "Connect" results, and a final online quiz.

Each Absorb-Do-Connect learning unit lasted two-three weeks, depending on the complexity of the unit's topics. For trial purposes, half of the course was restructured in Fall 2018; the Absorb-Do-Connect framework was only implemented for the MATLAB-Simulink portion of the course. MSC Adams course material was taught via the same manner as in past semesters, utilizing the freely available Adams Tutorial Toolkit (MSC Software) in an active learning environment. Semester grade distribution and other data from the restructured Fall 2018 course were compared to the most recent previous course offering, Fall 2016.

The authors wished to compare student opinions and learning outcomes regarding the active learning approach used for MSC Adams versus the new Absorb-Do-Connect framework implemented for MATLAB-Simulink. It was also desired to analyze the individual effectiveness of each phase of the Absorb-Do-Connect learning model. To do so, a link to a Qualtrics survey was sent via email to students at the conclusion of the Fall 2018 semester to voluntarily evaluate the effects of the course restructuring. The survey contained twenty-two statements, to which students were asked to select from one of five Likert-scale choices: Strongly Agree, Somewhat Agree, Neither Agree nor Disagree, Somewhat Disagree, and Strongly Disagree. Two survey questions were appropriated to each phase of the Absorb-Do-Connect framework to assess (1) effectiveness of each phase at helping students to learn the concepts, and (2) student engagement level with the activities of each phase. Another set of survey questions compared the active learning structure used to teach MSC Adams to the Absorb-Do-Connect framework for MATLAB-Simulink. Students were asked about their motivation to learn course content for each modeling platform as well as their confidence in their ability to utilize each software package to simulate real-world mechanical systems. Survey data was analyzed via SAS 94 English (SAS Institute, Cary, NC, USA) for statistical significance.

Modeling Dynamics terminates each semester with a significant group term project. Open-ended instructions encourage teams to develop a research question about a real-world dynamical system that can be investigated using the simulation tools taught in the course. Students often select to use their simulation term project to supplement Capstone Design or graduate research topics, which typically requires students to learn and implement techniques that extend beyond the scope of the course curriculum. The authors decided to analyze if the restructuring of the MATLAB-Simulink curriculum thru the Absorb-Do-Connect framework had improved depth and quality of group term projects in Fall 2018 when compared to Fall 2016. Preliminary post-hoc findings into this research question are reported herein.

Results

Course restructuring in Modeling Dynamics resulted in improved student grades in Fall 2018. Average grades increased by 0.19 points and the standard deviation of grade distribution was reduced by 40% (Table 1). There were zero C's or D's awarded under the new Absorb-Do-Connect instructional framework.

Table 1. Grade Distribution Across the Two Semesters.

		Grade		Number of:			
ME722	Students Enrolled	Mean	STD	A	B	C	D
Fall 2016	33	3.48	0.78	21	8	3	1
Fall 2018	31	3.67	0.47	21	10	0	0

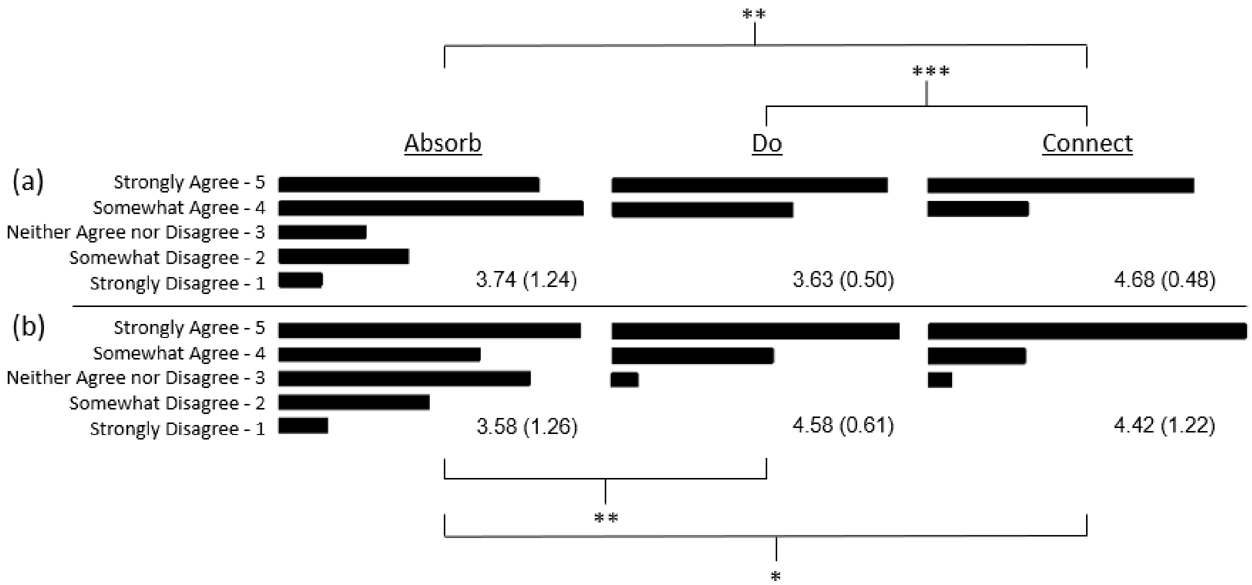

Figure 1. Student response distributions for survey questions (a) Activities were effective at helping me learn the concepts, and (b) I was fully engaged with the activities, with regard to each phase of the Absorb-Do-Connect learning units. Mean (Std. Dev.) scores shown for each question along with one-way Kruskal-Wallis ANOVA significance indicated at ***95%, **90%, *85% confidence levels.

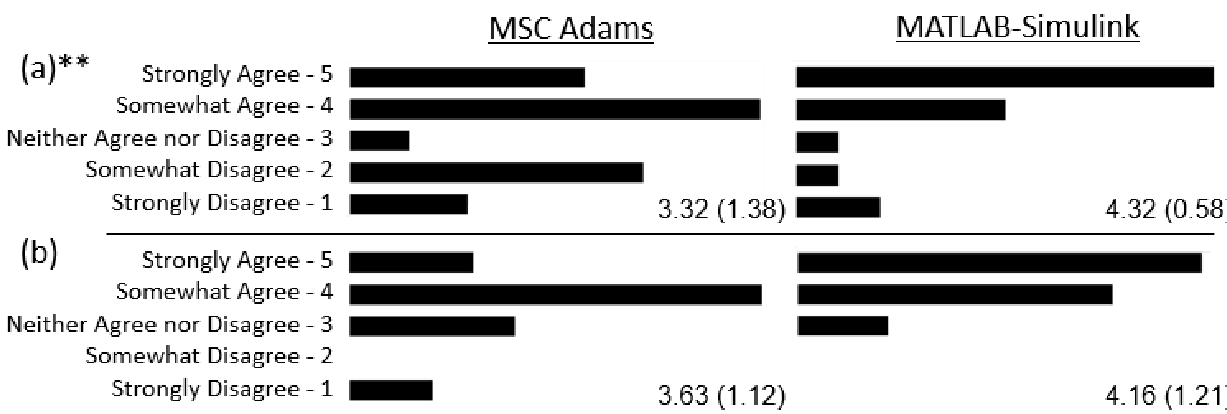

Figure 2. Student response distributions for survey questions regarding (a) student motivation to learn, and (b) student confidence in modeling abilities, with regard to the different instructional structures used to teach MSC Adams and MATLAB-Simulink programs. Mean (Std. Dev.) scores shown for each question. Paired t-test indicated significant differences in student motivation at **95% confidence level.

The electronic survey was sent to all 31 students during the last two weeks of the Fall 2018 semester. Nineteen responses were received. SAS was used to compare the engagement levels and effectiveness between the Absorb, Do, and Connect phases (Figure 1). Due to the non-normal distributions of student responses, which was expected, data was evaluated via the Kruskal-Wallis non-parametric method of one-way ANOVA. Students reported that the "Connect" activities were significantly more effective at helping them learn the concepts than both the “Absorb” ($p = 0.075$) and “Do” ($p < 0.001$) activities. Further, 100% of students who completed the survey agreed that *“working on the ‘Do’ and ‘Connect’ parts of each problem during class time was highly effective in helping [them] learn the course concepts”* and that the *“Absorb-Do-Connect activities built on each other appropriately.”* Responses also indicated that students were more fully engaged with both the “Do” ($p = 0.091$) and “Connect” ($p = 0.138$) activities than the “Absorb” activities. One in five students indicated very little or no engagement with the “Absorb” activities.

A paired t-test compared student responses for motivation and confidence levels between MSC Adams and MATLAB-Simulink (Figure 2). The Absorb-Do-Connect instructional framework used to teach MATLAB-Simulink motivated students to learn the course content significantly more than the active learning structure used to teach MSC Adams ($p = 0.011$). Further, students reported a higher level of confidence in their ability to utilize MATLAB-Simulink to model real-world mechanical systems than MSC Adams, though this difference was not statistically significant ($p = 0.213$, Mean Diff = 0.53). In response to the statement *“I learned more in the Adams part of the course compared to the MATLAB-Simulink part of the course,”* ten of the nineteen students disagreed while another seven students remained neutral.

Complementing students’ indication of higher confidence in using MATLAB-Simulink as a modeling tool, the Fall 2018 semester saw a dramatic shift in the simulation package(s) chosen by students for completing the term project (Table 2). A combined 77% of groups used MATLAB-Simulink for their Modeling Dynamics term project in Fall 2018, compared to 40% in Fall 2016 before the course restructuring.

Table 2. Term Project Simulation Program Chosen Across the Two Semesters.

		Number of Groups Choosing:		
ME722	Groups	MSC Adams	MATLAB/Simulink	Both
Fall 2016	10	6 (60%)	1 (10%)	3 (30%)
Fall 2018	13	3 (23%)	8 (62%)	2 (15%)

Discussion

Restructuring a course to the Absorb-Do-Connect framework can require a significant commitment of time and effort from the instructional team. However, our team views the benefits to outweigh the drawbacks. Absorb-Do-Connect learning units were well-received by the majority of students in Modeling Dynamics. Based on the results of this study, we conclude that it can also be a more effective method for student learning. While active learning environments have proven many times over to be more effective than traditional lecture classrooms (Felder, 2000; Freeman, 2014; Wankat, 2002), Absorb-Do-Connect blended active learning units demonstrate the potential to elevate student learning even further when implemented appropriately.

A primary advantage of Absorb-Do-Connect learning environments is the immediate feedback the instructor receives on student learning. For instance, the Fall 2018 instructional team realized very early in the semester that the intended pace of the course would be over-zealous based on students’ programming abilities. Students in Modeling Dynamics enter the semester with varying levels of programming skills, even though all students have previously taken a basic programming class. End-of-semester survey responses yielded a normal distribution in response to *“I had already developed strong programming skills prior to the* *beginning of this course."* This created a steep learning curve during the first few weeks of the semester for students who were learning basic coding language and syntax for the first time, as well as for students who were reviewing the basics of coding for the first time in several years. Other students who had strong programming backgrounds were able to immediately focus more of their attention towards understanding the problem statement for each learning unit because they were familiar with how to program the solution once it was determined analytically. To address this discrepancy, a short set of modules on "coding basics" are being developed for use at the beginning of the Fall 2019 semester with the goal of bringing all students' programming skills up to a level required to be successful in the course.

Through both classroom observation by the instructional team and the end-of-semester survey results, it was apparent that students were not fully engaged with the "Absorb" activities for MATLAB-Simulink. The intention of the "Absorb" activities was for students to review the provided solution code to a simplified modeling scenario and then complete a brief online quiz to demonstrate understanding. However, because the Absorb quizzes accounted for only a small portion of the grade for each learning unit, several students indicated that they were unmotivated to engage with the "Absorb" material. One student's survey response captures this shared attitude: *"I did not utilize Absorb to it's full potential. Perhaps I would have done better if I had. If I was really busy, it was one of the things that was easy to put in half effort [to complete]."* Students indicated higher engagement levels for both "Do" and "Connect" phases, perhaps because these activities were most similar to traditional homework assignments that students are accustomed to from other courses. In addition, most of the grade for each learning unit was accounted for by "Do" and "Connect" activities, which likely increased student motivation for these latter two phases. Nevertheless, the relatively lower efficacy of the "Absorb" activities allowed some students to arrive to class ill-prepared to offer meaningful contributions to the active learning "Do" exercises.

Ongoing work aims to improve the efficacy of the "Absorb" phase by requiring student interaction with the activities. Absorb quizzes will be replaced by fill-in-the-blank coding modules in an online environment, MATLAB Grader. Grader provides most of the essential features of MATLAB on an interactive web platform. Students complete coding exercises in the online environment and are provided immediate feedback and scores, similar to other online platforms commonly used in college science and engineering courses (i.e. Pearson Mastering, Maple TA). Student feedback supports this modification, with survey responses explaining that *"I've always learned better by actually doing an example [rather] than looking at it"* and that it was "*difficult to fully understand [the Absorb code] since it was already made."* The goal is that by developing simple interactive coding exercises for the "Absorb" simulations, students will be more motivated to engage with the content, preparing them to contribute more meaningfully to the in-class "Do" activities.

When asked if the Absorb-Do-Connect framework should be used to teach the MSC Adams portion of the Modeling Dynamics course, fifteen of the nineteen student survey responses were in agreement. Based on this feedback and input form the instructional team, the authors intend to complete the other half of the course restructuring in the coming semester. New Absorb-Do-Connect learning units will be developed to teach MSC Adams in the same manner as MATLAB-Simulink is taught. Other upcoming work will further investigate if the new instructional method led to higher quality and more 'in-depth' term projects.

In this paper, we have reported on the beneficial effects of restructuring a computer simulation course in modeling dynamics to the Absorb-Do-Connect learning model. Computer programming is very much a “crawl-walk-run” process by its nature. One must first understand simple codes before proceeding to develop more complex programs. In this way, programming and simulation courses seem to be ideal candidates for Absorb-Do-Connect learning units. However, the fundamentals of the Absorb-Do-Connect framework are intended to be universally adaptable to accommodate any course. In a sense, most required courses in engineering curricula (e.g. Calculus, Physics, Statics, Dynamics, Thermodynamics) already follow a general pattern of increasing complexity throughout the course of a semester. Restructuring a course with the Absorb-Do-Connect model overlays a formal sub-structure of increasing complexity within each unit topic as the course progresses. It remains to be seen, though, if the Absorb-Do-Connect instructional model is best suited for any specific discipline(s), course(s), and/or grade-level(s).

Conclusions

The Absorb-Do-Connect instructional framework was implemented in a computer simulation course in modeling dynamics. Results indicated that Absorb-Do-Connect blended learning units may be more effective than standard active learning environments in helping students to learn the concepts. Modeling Dynamics students reported that they were more engaged with the restructured course content and indicated higher confidence in their abilities to use the software to model real-world dynamics scenarios. Ongoing work aims to improve student motivation during the “Absorb” phase of the learning units and to develop Absorb-Do-Connect modules for a second simulation tool used in the course.

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