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Evaluation of Impact of Web-based Activities on Mechanics Achievement and Self-Efficacy

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Abstract

This paper presents initial results of a research project on the impact of web-based activities on mechanics achievement and self-efficacy. This pilot research is addressing the question of "What sticks and why?" in an introductory mechanics course that incorporates traditional lectures with interactive hands-on learning, as well as web-based instruction and homework. The web-based activities vary in level of interaction with the student. High interaction activities feature active learning with instant feedback; low interaction activities feature readings and lectures with demonstrations. Exercises focused on creating and using free body diagrams have been developed, and initial data on self-efficacy has been obtained. Additional studies will be conducted throughout the academic year.

The introductory mechanics course for which these web-based exercises are being created is taught to 80-90 students per term and involves hands-on laboratory exercises weekly within the class meeting time. The developed web-based exercises are for a one-week segment on free body diagrams and include video clips with opportunities for students to apply concepts both through multiple choice questions and interactive exercises. Class time during this week is devoted to additional hands-on exercises with some supplemental lecture content. Pilot data have been collected and results are reported on both the quantitative and qualitative information. Quantitative data include measures of performance on concept inventory questions and exams, as well as self-efficacy data. Qualitative information includes individual homework and in-class work as well as in-class pair work. In addition to presenting initial findings from our research, we will discuss how embedding of assessment into a course is benefitting both the students and the instructors.

1. Introduction

An introductory course on Solid Mechanics was recently redeveloped with a focus on active learning. The course is taught to 80-90 students per quarter and is a required fundamental course for several engineering majors. The authors have recently initiated an engineering education research project with this course as the platform. The focus of the research is on the use of online activities and how they may enhance student learning to improve self-efficacy and achievement, thereby boosting self-confidence of Engineering majors, and further serving to reduce drop out rates [4,10,24]. Different types of online activities to be investigated include variations on the level of student interaction in which "low interaction" activities are analogous to traditional lectures (watching demos with limited interaction) and "high interaction" activities have considerably more activity, interaction and feedback as in active (hands-on) learning.

Bandura [2] defined self-efficacy as a "belief in one's capabilities to organize and execute the courses of action required to produce given attainments." Since this time, many researchers have studied self-efficacy in engineering education. Ponton [18] highlights the importance and role of self-efficacy in motivation of students in engineering education. Marra [12] and colleagues performed a multi-institute study of self-efficacy in women engineering students, finding that self-efficacy is indeed related to women students' plans to continue in the traditionally male-dominated field of engineering. Similar observations have been found for minority students. With over 30% of the current freshmen at the authors' institution being from minority backgrounds (African American, Hispanic, Native American and/or Pacific Islander) and 16% first generation college students, methods for increasing self-efficacy through our teaching will be important to support and successfully educate a diverse student body in engineering.

With regard to self-efficacy in mechanics, Montfort [14] studied conceptual understanding of normal and bending stresses in civil engineering students after completing mechanics of materials (sophomore year), structural analysis (junior year) and steel design (senior year) and advanced steel design (graduate school). He found that seniors in particular had lower confidence in their conceptual understanding than both the younger students and the graduate students (who may have come from different undergraduate institutions). While not the focus of the study, all of the courses in the sequence studied were predominantly lecture-based. In a study on student use and learning gains from online statics courseware, Steif [28] found statistically significant learning gains from usage and in particular from self-regulated usage rather than total usage of the online statics courseware.

The introductory mechanics course used as the platform for our research is approximately half lectures and half in-class exercises. Given the findings of Montfort [14] and Steif [28], we are motivated to see if there is a tendency for concepts to "stick" better and lead to increases in both self-efficacy and achievement with different types of web-based exercises used to complement the in-class lectures and hands-on activities. With our research being embedded in the course offering a goal is to provide a natural blend of learner- knowledge- and assessment-centered environments, the three principles laid out in the 2000 National Research Council (NRC) report on *How People Learn* (NRC 2000) [15].

2. Interactivity

Interactivity is a model that is inherent to our research focus. Finding the "right blend" of interactivity is challenging yet ultimately provides the richest learning opportunity for both instructors and students [32]. Our understanding of interactivity draws from the studies of Moore [15], that there are 3 types of interactions commonly identified: learner-instructor, learner-learner, and learner-content.

Our focus on the *learner-instructor interaction* involves engaging a team of 1-2 faculty and 4-6 course assistants who are graduate students at the university. Each course assistant is responsible for 20-23 students to aid in class discussions, communicate logistics in class as well as between classes, hold face-to-face meetings, and provide frequent feedback in-class exercises and assignments. These activities are performed to stimulate student interest and motivation, organize application of student learning, counsel support, and encourage each learner. The teaching team as a whole serves as a facilitator, mentor, guide, and coach whose roles are pedagogical, social, managerial, and technical[35] to support our course model learning activities.

The *learner-learner interaction* used in our model is the type of interaction that is accomplished between one learner and other learners, either alone or in a group setting. Our course model emphasizes group work and discussions, self-assessments, and team projects. Numerous studies have shown positive impact on how interaction with other learners is the basis of transformative learning and can foster powerful relationships, improve student outcomes, increase student motivation, foster higher order thinking and creativity, and enhance student involvement [24]. Furthermore this type of interaction has been shown to have positive effect on student retention, participation and goal achievement [24].

The *learner-content interaction* is typically defined as the type of interaction where the learner interacts intellectually with the content. This type of learning involves conflict or puzzlement in the learner's mind and when intervened with expert explanations (via our teaching team) often results in improvement of material concepts in the learner's understanding, perspective, and cognitive structures in the mind [8,31]. We incorporate class-seating arrangements, self assessments using brief course concept quizzes, and minute papers in our course model.

With the rise of online courses, another type of interaction gaining momentum in the discussion of "interactivity," is *learner-interface interaction* [7,23]. This type of interaction is investigated in our course model through the web-based activities, and as mentioned previously varies in level of interaction with the student. High interaction activities feature interactive assignments that will give students the instant feedback they need. These assignments are self-graded as a way of checking their understanding of material concept. Low interaction activities feature readings and online lectures with demonstrations. The web-based activities are the focus of the research presented in this paper.

In a hybrid course such as ours, often it is difficult to separate the different types of interactions and overlapping may occur; thus we are aware that the 4 types of interactions are not mutually exclusive.

3. Research Context

Table 1 outlines the weekly topics covered in lecture as well as the student activities and learning outcomes for each week for the introductory solid mechanics course. The bulk of the class is similar to introductory statics courses but also includes several topics covered in introductory mechanics courses.

The constructs of self-efficacy and achievement are defined as follows. By achievement we mean learning the body of knowledge and skills associated with introductory solid mechanics (including statics). Self-efficacy refers to the state of mind that allows a student to move ahead through the inevitable obstacles and failures that are part of the learning of a difficult body of knowledge and skill [2,3,6]. The required course in mechanics is often the student's first encounter with genuine engineering concepts and problems. Unlike physics, the problems are "real world," complex situations where the first task is often clearing away irrelevant clutter to see an idealization of the structure to be analyzed. Within a short period of time, engineering students are expected to make substantial progress toward skills and knowledge typical of experts [5].

Table 1 Student Activities and Learning Outcomes in *Introduction to Solid Mechanics*

Week	Topic	Student Activities	Learning Outcomes
1	Forces	Lab: Design Exercise	Hands-on design & testing experience with constraints
2	Moments	Demos: Devices & Body	Identify moments created by forces on various devices
3	Equilibrium of Forces and Moments	Plank experiment, Roadmaps & Small group problem solving	Apply equilibrium conditions to planar systems
4	Free Body Diagrams (FBDs)	Lab: Devices; Roadmaps & Small group problem-solving	Draw FBDs based on physical systems; use FBDs as basis of equilibrium analysis of non-planar systems
5-6	Equilibrium Analysis of Trusses	Case study and Bridge design project	In a team, design, analyze, build and test a truss structure to failure
7	Equilibrium Analysis of Machines	Lab: Bicycle analysis	Calculate mechanical advantage using free body diagrams
8	Beams	Lab: Calculating bending stress in beams	Map loads to stresses, distinguish between normal and shear stresses, predict angle/mode of failure
9	Statically Indeter-minate Problems	In-class Homework Assignment	Solve a statically indeterminate problem and execute stress transformation equations
10	Distributed Loads	In-class Homework Assignment	Solve equilibrium problems based on friction forces

4. Research Objective and Questions

The objective of the research is to explore how the trajectories of student self-efficacy and achievement in the field of mechanics are influenced by variation in web-based activities designed to complement in-class activities and homework. This idea is depicted schematically in Figure 1, where different students (different shaped markers in orange in Figure 1) begin with a certain self-efficacy and achievement in mechanics and over time (orange arrows) and, following exposure to varying types of web-based activities show increases or decreases in self-efficacy and achievement (yellow or blue markers where yellow represents usage of one type of web-activity and blue represents another).

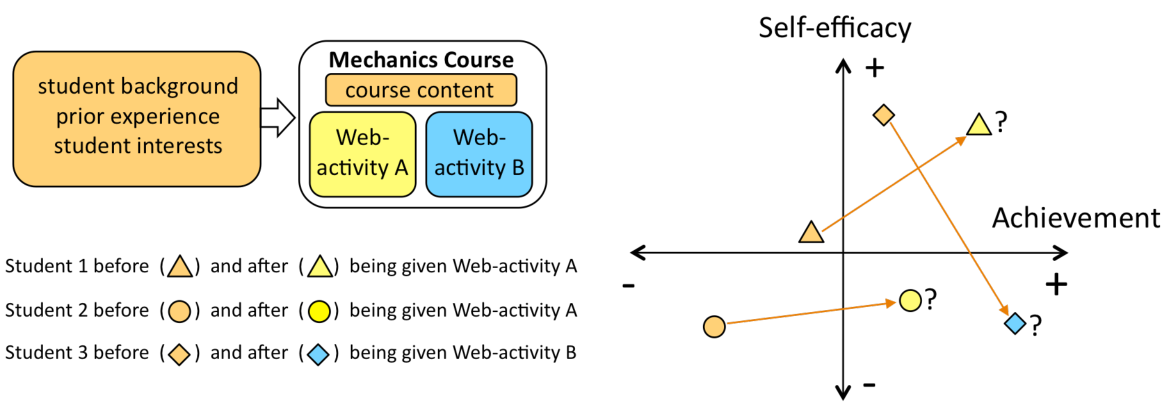

Figure 1. Schematic of how web-based activities may impact mechanics self-efficacy and achievement.

Our primary research question is: Under what conditions (e.g., student background and interests, prior experience, course content) does variation in the substance and style of web-based exercises during the introductory course in mechanics impact student self-efficacy and achievement?

Web-based exercises provide opportunities for students to engage in interactive experiences. These interactive experiences are envisioned to range from reading and linking to multiple sources for additional information or demonstration videos ("low interaction") to highly interactive "hands-on" learning with feedback and support when students make mistakes. In general, web-based activities, particularly highly interactive ones, can provide richer and timelier feedback that addresses students' successes. The online statics courseware described by Steif [29] exemplifies highly interactive web-based activities.

We hypothesize that augmenting class lectures and student activities with web-based exercises will in general lead to increases in self-efficacy and achievement as measured during the course as well as three months after completing the course. One reason for this hypothesis is what we see as a high potential to scaffold learning through web-based activities that can guide students through the ambiguity of authentic engineering questions in this early-stage course [34]. We further hypothesize that, during the course, students with greater exposure to more interactive web-based activities, which provide immediate feedback for students on a given topic along the way (allowing for self-regulation), will show increased self-efficacy and achievement in solving new problems related to those topics [29], compared with those exposed to the more information-based, "low interaction" activities.

5. Research Methods

Figure 2 depicts the original design of the study and the data types we plan to collect. As shown in Figure 2, the 80 students in the course are randomly assigned to a pod of 20 students, each named after the suits in a deck of cards and each assigned one to two course assistants as discussed in Section 2. This practice of creating groups within the larger class has been used for several years for small group in-class exercises.

To date, we have developed and deployed a pilot version of online activities for Weeks 4 and 5 on the topic of Free Body Diagrams. A schematic of what was developed is shown in Figure 3. Two sets of online activities were developed; one included with Homework 3 assigned in Week 3 and due at the end of Week 4 and one included with Homework 4 assigned in Week 4 and due early in Week 5. In between these Homework assignments, one class period was devoted to in-class exercises on creating free body diagrams from figures, photographs and hand-held devices, both by individual students and in teams of 2-3 students.

With further development of online activities in the coming year, the research design will incorporate variations in the order in which web-based activities are provided, and the "amount" of such activities, permitting the evaluation of questions about dosage and timing. Our first set of activities does not have a variation of high and low interaction components although these are planned for the future to serve as treatment factors. We envision "High interaction" material to be activities that involve student participation in learning (e.g., apply forces to maintain equilibrium) and give feedback during the exercises. "Low interaction" activities will incorporate more textbook-like content with links to occasional animated examples, readings, and facts. The current set of exercises for which we have preliminary data incorporates both features as we are evaluating their use in the class.

In the long term, the research design provides both between- and within-student variation in this factor (high and low online interaction). The first two weeks of the course are devoted to review of two topics with which all of the students have some previous familiarity during high school and/or college physics courses. All groups will participate in high and low interaction exercises during one of the two weeks in a counterbalanced order as shown in Figure 2. This between-student variation provides an introduction to the online activities, and allows a test of order effects for this variation.

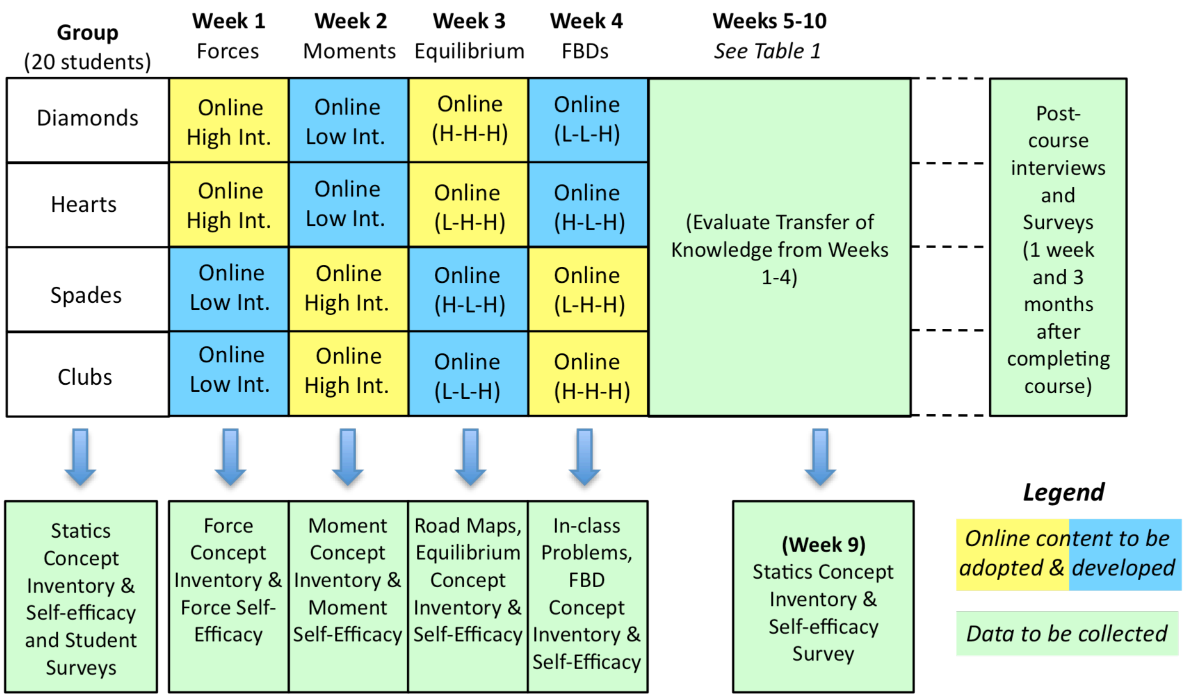

Figure 2 Proposed incorporation of online material into ***E14: Introduction to Mechanics of Solids*** and data to be collected.

In developing our first set of exercises for Week 4 on Free Body Diagrams, we have organized our research around five tasks: (1) Select and Develop Inventories and Surveys, (2) Develop and Adapt Web-based Activity Materials, (3) Develop and Adapt In-class Activity Materials, (4) Collect Data, and (5) Analyze and Interpret Data. Progress in each of these tasks is described further next.

Background Survey: A background survey is used in the class to assist in selecting the enrollment when more than 80 students register for the class. Questions asked in this survey relevant to this research include previous math and science courses taken (in particular whether or not the calculus-based physics class focused on mechanics has been completed), declared or intended major if any, student year (e.g., sophomore, junior), and gender. In the background survey the students are also asked to complete a brief math quiz to assess their strengths and weaknesses in particular with working with vectors. They are also given several statics questions related to concepts of equilibrium. Finally, they are asked a set of self-efficacy questions as described next.

ONLINE ACTIVITY ASSIGNMENTS RELATIVE TO OTHER CLASS ACTIVITIES						
Week	**Week 3 (Equilibrium)**		**Week 4 (Free Body Diagrams)**		**Week 5 (FBDs & Trusses)**	
Day	**Tuesday**	**Thursday**	**Tuesday**	**Thursday**	**Tuesday**	**Thursday**
Class Activity	Lecture	Lecture Lab (Longboard)	Exam 1 Lecture (Strength)	mini-Lecture In-class FBD exercises	Lecture	Lecture
Homework		HW2 Due; HW3 Assigned		HW3 Due; HW4 Assigned		HW4 Due
Online Activity			Online portion (HW3) open after class	Online portion (HW3) due prior to class Online portion (HW4) open after class	Online portion (HW4) due prior to class	

DATA COLLECTED AROUND ONLINE ACTIVITIES						
Week	**Week 3 (Equilibrium)**		**Week 4 (Free Body Diagrams)**		**Week 5 (FBDs & Trusses)**	
Day	**Tuesday**	**Thursday**	**Tuesday**	**Thursday**	**Tuesday**	**Thursday**
Class Activity	Lecture	Lecture Lab (Longboard)	Exam 1 Lecture (Strength)	mini-Lecture **Wk4 Individual and pair work on creating Free Body Diagrams**	Lecture	Lecture
Homework		HW2 Due; HW3 Assigned		HW3 Due; HW4 Assigned		HW4 Due
Online Activity			**Wk4 Self-Efficacy Pre-and Post-Exercises; Wk4 Performance**	**Wk5 Self-Efficacy Pre- and Post-Exercises; Wk5 Performance**		

Figure 3. Details of when online activities were assigned and when data were collected.

Self-efficacy Questions: Two sets of seven questions were developed to measure self-efficacy. The first set concerns student confidence while the second set ask about perceived difficulty. Together they provide two items for each topic that can be evaluated for their possibility of "scaling" together. The questions asked are shown in Figure 3. The questions are each asked using a Likert Scale from 1 to 6 where each number refers to a specific phrase as shown in Figure 4. A Likert scale of 1 to 6 was selected to remove the possibility of picking a middle point.

Online Exercises: Two sets of online exercises were developed and incorporated into an online learning platform developed through the OpenEdX consortium. In the first set of questions, the objective was to provide a review for students in terms of identifying a free body diagram from a larger system as well as labeling the types of forces (e.g., internal, external) acting on the subsystem identified. An example is shown in Figure 5a. Three different scenarios of the questions around this set of blocks were created. Next, a similar set of questions was asked around a more realistic system of a diver on a diving board (Figure 5b). Here students were asked to drag and drop appropriate arrows onto the system of the diving board to create a valid free body diagram. Finally, after introducing several realistic two-dimensional support systems (e.g., pin, roller, fixed support) students were asked to add the forces to a free body diagram of the diving board now drawn with a pin and roller support.

On a scale of 1 (No Confidence) to 6 (Completely Confident), how confident are you that you can:

	Totally Unsure	Very Doubtful	Probably Not	Maybe	Pretty Sure	Definitely Sure
Draw a free-body diagram?						
Write the equations of equilibrium for a system?						
Carry out the problem-solving process to analyze a system?						
Compute the cross product of two vectors?						
Identify force couples acting on a system?						
State Newton's Three Laws of Motion?						
Overall, perform the work needed to complete all of the above tasks?						

On a scale of 1 (Very Easy) to 6 (Very Hard), how difficult do you consider each of these tasks:

	Very Easy	Easy	Moderately Easy	Moderately Hard	Hard	Very Hard
Draw a free-body diagram.						
Write the equations of equilibrium for a system.						
Carry out the problem-solving process to analyze a system.						
Compute the cross product of two vectors.						
Identify force couples acting on a system.						
State Newton's Three Laws of Motion.						
Overall, the skill and knowledge needed to complete all of the above tasks.						

Figure 4. Questions posed to measure self-efficacy

All of the questions were formative in that students could submit their answer to see if it was correct (green check) vs. incorrect (red X). Students were permitted to submit an answer as many times as desired. Records of the number of attempts made by the student were kept as well as if the students' answers were correct or not on their last attempts. The ability to track precisely how many attempts it took to achieve a correct answer, the different answers selected and the amount of time spent on a question is currently not available to the researchers but the capability is being sought for future research.

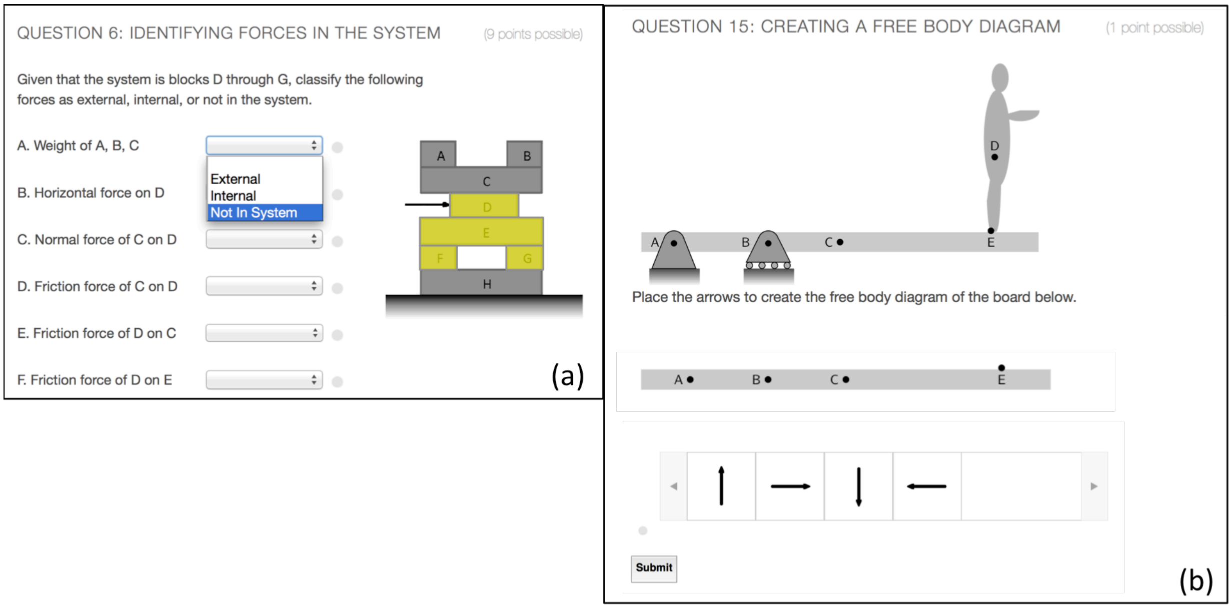

Figure 5. Examples of online questions for (a) identifying forces on a free body diagram, and (b) creating a free body diagram. Problem Statements are included at the top of each figure.

In the second set of online exercises to be completed by the beginning of Week 5, the objective was to have the students learn a new concept about free body diagrams and apply it to a scenario problem. The concept presented was the use of more than one free body diagram in a single system to solve for unknown forces, where just one diagram was not enough. In this set of exercises, students learned how to create free-body diagrams for exiting structures by watching two brief (3-7 min.) videos wherein a free-body diagram was created for a cantilever monument and the main span cable of a suspension bridge. The exercise for the students to complete was then to identify appropriate free-body diagrams and equilibrium equations for a three-hinged reinforced concrete arch loaded at its quarter points (with idealized truck loads). They were also asked to solve for the value of the unknown forces. As with the first set of online exercises in Week 4, students were permitted to submit an answer as many times as desired. Records of the number of attempts made by the student were kept as well as if the students' answers were correct or not on their last attempts. Most of the questions were multiple choice while others required identifying (clicking on) parts of the system and others required adding force vectors (arrows) to create an appropriate free body diagram.

As mentioned previously, the online exercises were created in an EdX platform, which allowed us to capture each student's learner-interface interaction. This environment of learning through "doing" via online exercises is a major part of our research investigation (do web-based activities impact student learning and how do they relate to student's mechanics self-efficacy and achievement?). We hypothesize that the visual nature and interactivity of these online exercises are positive features that may aid learning; they are seen as "little learning engines" that are designed to promote learning through practice and interactivity. In the particular example of Figure 5(b), students were asked to "drag and drop" arrows representing support reactions and external forces on the horizontal beam.

The OpenEdX platform we used has an automatic-grading function as well as other formats of asking questions, such as blank common problems, checkboxes, dropdown, multiple choice, numeric input, and text input. The rigours of the free-body diagram in the online exercises are then extended and carried into in-class exercises, where students translate their knowledge of constructing complete and correct free-body diagrams using paper and pencil. OpenEdX has several effective storage capacities in terms of recording student "movement", such as time per question, answer in each attempt (if multiple attempts to answer a questions were allowed). The collection of data on student "movement" is still in progress this term.

In-class Exercises: Between the two homework assignments that included the online exercises, one two-hour class period (at the end of Week 4) was devoted to in-class exercises on creating free body diagrams. For these exercises, students were asked to create free body diagrams from textbook figures, from photographs and from handheld devices. Examples are given in Figure 6. Both individual and pair work was collected from the students for evaluation.

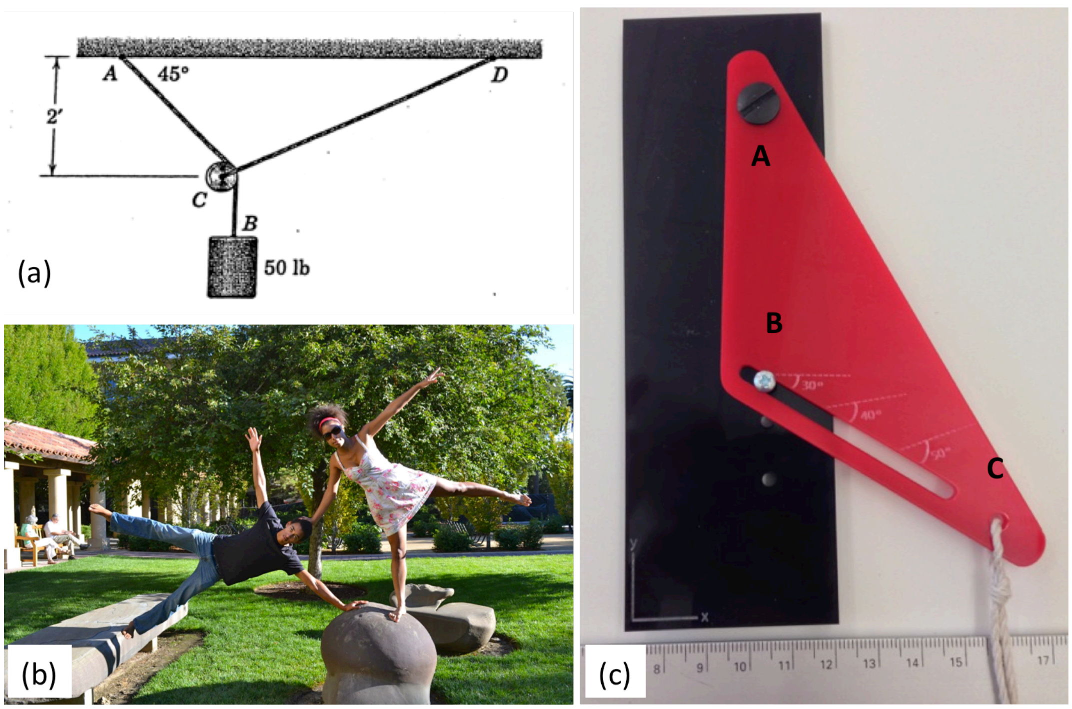

Figure 6. Systems used for in-class exercises on creating free body diagrams from (a) textbook figures, (b) photographs, and (c) hand held devices passed out in class.

6. Research Findings to Date

To date, data have been collected from one course offering in fall 2013 (~90 students) and includes:

(1) background survey information from Week 1,
(2) self-efficacy responses at the beginning of the course (Week 1) and at the beginning and completion of the two sets of online exercises (Week 4 and Week 5),

(3) participation, number of attempts and correctness of two sets of online exercises on the topic of free-body diagrams (Week 4 and Week 5), and
(4) in-class individual and pair work on creating free body diagrams (Week 4).

Our primary research focus is to investigate under what conditions (e.g., student background and interests, prior experience, course content) do variation in the substance and style of web-based exercises during the introductory course in mechanics impact student self-efficacy and achievement? Is there variability among our observed variables? Furthermore, can we remove redundancy or duplication from our set of correlated variables? Thus we used Factor Analysis to potentially identify latent independent variable(s) associated with the Self-Efficacy Confidence and Difficulty measures in Figure 4. We will explore how these measures change over time and how we can combine the scores across administrations into a more meaningful measure or indicator of self-efficacy. We have begun to analyze the first 3 items of data listed above. In particular we have:

- Reliability runs on several dependent variables, including the Confidence/Difficulty scales for the Self-Efficacy measures and the Outcome/Performance measures (Number of Attempts and Correct/Not Correct)
- Descriptive statistics for all of the measures and background factors.
- Correlations and factor analyses of the Self-Efficacy measures to determine the simple structure of these variables
- Correlations among the Outcome/Performance measures

The preliminary analyses reported here cover the Self-Efficacy measures collected during the experimental sessions during Weeks 4 and 5, along with background and performance measures from the beginning of the course. Performance measures from the end of the course are being evaluated as well but are not reported here. The analyses cover the reliability and factor structure of the various measures, and the relation between the Self-Efficacy and Performance measures.

6.1 Self-Efficacy – Weeks 4 and 5

The Self-Efficacy measures included parallel surveys of Confidence and Difficulty, with seven items on each scale, along with an "Overall" item. Pre- and Post- surveys were administered for Weeks 4 and 5. Table 1 shows the Cronbach's Alpha for each scale and administration. The alpha coefficient for the different administrations are all above .70, suggesting that they have relatively high internal consistency. The maximum and minimum means are double- and single-underlined, respectively for comparison across scales and administrations. Six-point Likert scales are anchored at "6" for "Very Confident" and "Very Difficult." Therefore the maximums for the confidence scale are large numbers and the maximums for the difficulty scale (to compare high confidence with easiness) are low numbers.

Table 1. Item Analysis for Self-Efficacy Measures *(See Figure 3 for when Week 4 (Wk4) and Week 5 (Wk5) data were collected; Pre refers to prior to completing the exercises; Post refers to after having completed the exercises; Conf. and Diff. refer to the confidence and difficulty questions, respectively, from the self-efficacy measures shown in Figure 4).*

ADMINISTRATION	Wk 1 Confid	Wk 1 Diffic	Wk4 Pre Confid	Wk4 Pre Diffic	Wk4 Post Confid	Wk4 Post Diffic	Wk5 Pre Confid	Wk5 Pre Diffic	Wk5 Post Confid	Wk5 Post Diffic
N=Sample Size	91	91	80	80	76	76	77	77	79	79
Cronbach's Alpha	.85	.86	.79	.89	.87	.91	.79	.92	.88	.94
Draw free body diag.	5.494	2.3111	5.42	2.49	4.800	3.036	5.01	3.08	4.974	3.000
Write equil. eqns. for system	5.044	2.8333	5.47	2.46	5.288	2.470	5.30	2.61	5.462	2.443
Carry out prob. solv. process	4.934	3.2556	5.22	3.11	5.125	2.855	5.09	3.01	5.244	2.582
Compute cross products	5.252	2.1778	5.70	2.06	5.538	2.133	5.55	2.11	5.500	2.051
Identify force couples	5.022	2.8556	5.35	2.54	5.150	2.614	4.93	2.78	5.141	2.557
State Newton's 3 Laws of motion	5.560	1.8222	5.11	2.33	5.113	2.289	5.12	2.46	5.141	2.342
Overall, perform the work	5.241	3.0000	5.29	2.84	5.013	2.819	5.05	2.96	5.15	2.658

The item means show that "Vector cross products" is uniformly judged as "most confident" and "least difficult" of the items. In general, students are quite confident, with means at or above 5.0 on a 6-pont scale, and judge the tasks all to be relatively easy. As will be discussed further with the factor analysis, there is a difference captured between Week 1 and Weeks 4 and 5 but no significant trends across administrations for Weeks 4 and 5.

Correlations among the self-efficacy scale scores are generally moderate to high, ranging from .4 to .6, which corresponds to 15 to 35 percent shared variance. A factor analysis was conducted across administrations and scales (including Week 1) to determine the factor structure (Tables 2 & 3); the solution was restricted to two factors. This method of data reduction is done to seek underlying unobservable (latent) variables that are reflected in the observed administrations. As seen in Table 2, the two factors selected had eigenvalues of 1.00 or greater. This approach is the default in most statistical programs, such as SPPS (the program used in the analysis of our study), where eigenvalues are used to condense the variance in a correlation matrix, and as in our case, the two factors with the highest eigenvalues are the ones that have the most variance. Most practices in Factor Analysis encourage only factors that explain the same amount of variance as a single variable is worth keeping. The first factor was the difference between the pre-class surveys (Week 1) and the Week 4 and Week 5 surveys and the second factor measures differences between difficulty and confidence across all administrations.

Table 2. Factor Analysis Results

Factor	Initial Eigenvalues		
	Total	Variance %	Cumulative
1	6.001	60.005	60.005
2	1.039	10.386	70.391

Table 3. Factor Loadings

Factor Loadings	**Factor**	
	1	2
W1SEConfAve	-.173	**-.868**
W1SEDiffAve	.288	**.833**
W4PreSEConfAve	**-.749**	-.336
W4PreSEDiffAve	**.719**	.375
W4PostSEConfAve	**-.817**	.002
W4PostSEDiffAve	**.862**	.187
W5PreSEConfAve	**-.745**	-.351
W5PreSEDiffAve	**.736**	.436
W5PostSEConfAve	**-.737**	-.320
W5PostSEDiffAve	**.678**	.433

A two-factor fit to the data were quite adequate, accounting for 70 percent of the variance. The factor structure presents a pattern that is consistent with other self-efficacy findings, in that the two factors reflect the differences between the initial pre-course administration of the survey (Factor 2) and the administrations during the experimental sessions (Factor 1). The Confidence and Difficult dimensions behave similarly, according to the analysis results.

From the Factor Loading results it is clear that both factors are picking up the differences between administrations in Week 1 and in Weeks 4 and 5; these results suggest two “clusters” of self-efficacy measures, each into a homogeneous set of variables. These clusters provide insight into the two categories that effect student self-efficacy. In the next stage of our research we will investigate how the levels of interactivity affect the underlying factors found.

6.2 Performance Outcomes – Weeks 4 and 5

Two performance indicators were collected during the experimental computer exercise in Weeks 4 and 5: *Attempts* was a count of the number of clicks that a student made while working on an item, and *Correct* was a code to indicate whether the final response was correct (1) or incorrect (2). Table 4 displays the alpha values and means for each of the indicators for each week.
The first analysis of the reliability of the two Attempt scales showed that there was an outlier for each scale, a problem in which the number of attempts was ten times larger than for the other

problems. The outlier was deleted from each scale, and the table shows the results for the reduced scale. The data for Table 3 can be interpreted as follows. The average of 1.5 attempts means that for most problems and students, a single attempt resulted in a correct response (the average Correct is .99 and .95 for Weeks 4 and 5). In some instances, it took two attempts for a correct response, and in rare instances a third attempt was needed. One explanation for this finding is that students studied each problem carefully before making an attempt, which would have been revealed from the study time. Unfortunately study time could not be captured in the online platform. The other possibility is that the exercises were relatively simple, and posed little challenge for the students. Evidence about this possibility might be found by examining scribbles on the notebook pages that students used to work out the answers.

Table 4. Item Analysis Results for Performance Outcomes

	Week 4		Week 5	
	Attempts	Correct	Attempts	Correct
Cronbach's Alpha	.81	.99	.63	.95
Mean	1.5	.93	1.5	.95
Standard Deviation	.51	.71	.70	.17

In addition to analyses described above, the authors are performing analyses of the relations between Weeks 4 & 5 outcomes and the final course grade as well as relations between the final course grade and both self-efficacy and selected background factors.

7. Discussion

7.1 Observations and Challenges

The Self-Efficacy scales seem to be working well in that the Confidence and Difficulty scales are reliable on all five administrations, and can likely be streamlined in future data collection. Student feedback indicated that the questions were asked too often so in the next offering we will be asking these questions at the beginning of the Week 4 exercises and at the end of the Week 5 exercises (i.e., three administrations in all).

In terms of the Outcome and Performance measures (i.e., Number of Attempts and Correct/Incorrect), they are not functioning well. They do not have a great deal of variability and as of now are poorly correlated. They will not be effective in evaluating program variations on their own and other additions such as exam scores are being evaluated for use in the main investigation. In addition, more challenging problems are likely needed as well as ones that work well with multiple choice formats and other well-supported options on the current online course platform.

The in-class work on free body diagrams still needs to be evaluated but involved so many small items being distributed along with many sheets of paper that the exercises will need to be streamlined. In addition, students did not like working individual problems and then creating a solution in a pair for the same problem, as it was too repetitive. A new pair problem will be introduced that addresses a similar challenge as the individual work.

7.2 Impact on teaching in other courses

In addition to the findings of the research conducted here, a positive impact of this work has been its extension to other course offerings. In particular, self-efficacy questions were adapted for a graduate course on Structural Concrete to serve as an additional course assessment. The results are shown in Figure 7. The results being focused on the actual course content were more informative to the instructor than standard course evaluations that focus on more generic questions. Through the self-efficacy measures it was identified that more focus on the teaching of the topic of two-way slabs would improve student learning in this area.

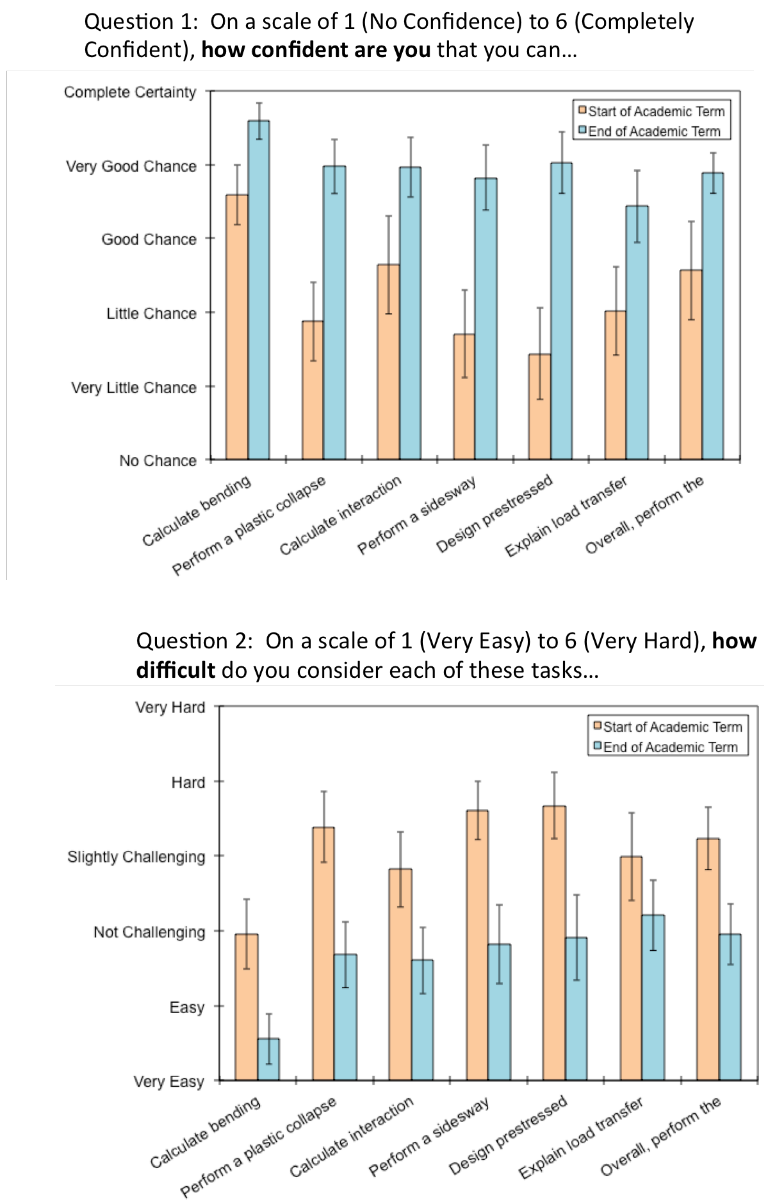

Figure 7. Transference of self-efficacy research to another course offering

8. Next Steps

In the current offering of the course, the authors are using a revised set of the first online exercises to be more challenging in content and easier to use with the online platform. A goal of the new set of exercises is to make an impact on student learning in Weeks 4 and 5 through the use of the online exercises. We will also be analyzing the in-class work on free body diagram development both from the fall as well as the current offering. We will also reduce the amount of times the self-efficacy questions are asked, as this was not popular with the students. Finally, new efforts will include developing the exercises on Equilibrium for Weeks 2-3 and exploring ways of creating more interactive and more traditional and less interactive versions of the online learning exercises with the OpenEdX platform.

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