Learning Statics by Feeling: Effects of Everyday Examples on Confidence and Identity Development

Ms. Janet Y Tsai, University of Colorado at Boulder

Janet Y. Tsai is a doctoral student at the University of Colorado, Boulder, whose work examines and develops initiatives to encourage more students, especially women, into the eld of engineering. Currently, Tsai's research focuses on understanding the dynamics of how status and prestige are constructed among novice engineers.

Dr. Daria A Kotys-Schwartz, University of Colorado Boulder

Daria Kotys-Schwartz is the Design Center Colorado Co-Director and an Instructor in the Department of Mechanical Engineering at the University of Colorado Boulder. She received B.S. and M.S degrees in mechanical engineering from The Ohio State University and a Ph.D. in mechanical engineering from the University of Colorado Boulder. Dr. Kotys-Schwartz has focused her research in engineering student learning, retention, and student identity development within the context of engineering design. She is currently investigating the impact of a four-year hands-on design curriculum in engineering, a holistic approach to student retention, the effects of service learning in engineering education, and informal learning in engineering.

Prof. Michael Patrick Hannigan, University of Colorado - Boulder

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Abstract

A novel teaching approach, the Body-Based Approach, uses the framework of active learning to structure the implementation of everyday engineering examples in recitations as part of an Engineering Statics course in fall 2012 at a large public university. As the gateway course to many engineering disciplines, Statics is typically the first technical engineering course an aspiring undergraduate takes and is frequently a prerequisite for subsequent technical requirements along the engineering pathway. With a class size of approximately 200 people at such a focal transition point, mandatory 50-minute active learning recitations were added to a twice-weekly lecture for Engineering Statics with the aim of improving the educational experience for the students. A total of 6 recitation sections were split equally into two flavors depending on the type of examples used: Body-Based or Traditional (recitation class size = 35, total students = 200). All recitations incorporated active learning activities and awareness of the situated process of learning, with care taken to select relevant and easily relatable examples for students to physically interact with and learn from. While the Body-Based Approach uses different aspects of the body and internal body sensations to illustrate concepts like Forces, Moments, Friction, Equilibrium, and Distributed Loading, the Traditional Approach uses more traditional examples including C-clamps, desk chairs, trees, and other objects that are separate from the body but still tangible. During recitations, students worked in small groups of 3 to 4 students to complete a variety of learning activities using either Body-Based or Traditional examples, under the guidance of two co-instructing recitation instructors. Recitations were formatted to align with the *Engage Engineering Everyday Examples in Engineering (E^3) Initiative*[1].

The resulting changes to student conceptual knowledge, feelings of belonging, confidence, and engagement are being examined both quantitatively and qualitatively during the course of the semester. This paper introduces the research design, provides examples of the curriculum, and gives details on executing such a course model with a team of recitation instructors. Additionally, initial analysis of the Pre-/Post- Concept Inventories and selected confidence items from Pre-/Post- Engineering Attitudinal Surveys will be presented for discussion.

Introduction

Engineering Statics is the traditional gateway course through which young undergraduate students must pass in order to complete engineering degrees and take higher-level classes. Required for Mechanical, Aerospace, Civil, Environmental, and many other engineering disciplines, Statics often serves as a prerequisite and foundation for the technical core of engineering subjects including Dynamics, Mechanics of Solids, Fluids, Thermodynamics, etc. Typically taken in the first semester of the 2nd year of a standard 4-year engineering undergraduate curriculum, success in Statics is critical for continued success along the pathway to an engineering degree. As the first technical engineering class students encounter, Statics has the potential to make novice students excited and enamored with the engineering problem-solving and analytical process, or conversely students' experience in Statics can cause them to switch disciplines or feel discouraged about pursuing engineering. It is a focal class in the trajectory of undergraduate engineers; as such it is a ripe area for investigation and innovation by engineering educators and researchers.

As colleges and universities look to retain students in engineering and encourage students to pursue engineering careers, alternatives to the traditional lecture model are becoming increasingly accepted as methods to increase student engagement and improve the overall learning experience. Active learning is one such approach, defined broadly as "any instructional method that engages students in the learning process"[2]. Active learning encompasses *collaborative* learning, a method in which students work together in small groups, *cooperative* learning, in which students pursue common goals while being assessed individually, and *problem-based* learning, in which relevant problems are used to provide context and motivation for learning[2]. *Collaborative*, *cooperative*, and *problem-based* learning are among the most thoroughly discussed active learning methods[2–5].

The Engage Engineering project utilizes *problem-based* learning as one of "three research-based strategies to improve student day-to-day classroom and educational experience," referred to as E^3s or Everyday Examples in Engineering[1]. Motivated by the idea that students learn better when they are comfortable with the context and meaning of the teaching examples used in lessons, the Everyday Examples in Engineering project uses objects that students are familiar with (iPods, sausages, bicycles, etc.) to teach fundamental engineering concepts[6-7]. Sponsored by the National Science Foundation (NSF), the Engage Engineering project has partnerships with over 30 universities and engineering colleges nationwide to implement E^3 lesson plans and develop new everyday examples that can be used to teach engineering concepts at the undergraduate level[1].

E^3 lesson plans have been mostly formulated based on the 5 E's format: *Engage*, *Explore*, *Explain*, *Elaborate*, and *Evaluate* [8-9]. This format, introduced by Atkin in 1962, is based on a constructivist view of knowledge creation that encourages students to build their own understanding of new ideas[8]. Beginning with *engage,* students first encounter the topic at hand as the lesson is designed to get their attention and interest from the start. The *explore* stage affords students the opportunity to get directly involved with the lesson through some type of inquiry-based learning activity facilitated by the instructor. The middle *explain* stage asks the students to put what they learned or experienced during the *explore* stage in words. In the fourth stage, *elaborate,* students expand on what they have learned and begin to extend and apply their knowledge to new areas. Finally, in the *evaluate* stage the student has the chance to demonstrate their knowledge and understanding of the topic[10]. Utilizing the 5 E's as the standard lesson plan format for Everyday Examples in Engineering allows exemplary lessons to be easily disseminated to a broad audience of engineering educators for use in the classroom; in fact the sharing of examples and lessons is one of the primary aims of the Engage Engineering project[1].

The effect of Everyday Examples in Engineering on student confidence is relatively unknown, as the Engage project is largely focused on how these lessons are implemented in the classroom and how they affect student retention within engineering majors. Student confidence has many different definitions and constituent categories, including the new concept of *professional role confidence*. Introduced in 2011, *professional role confidence* is comprised of two primary dimensions that readily apply to engineering: *expertise confidence*, or confidence in one's ability to possess the skills and expertise necessary for engineering practice, and *career-fit confidence*, or confidence that an engineering career path is well matched to one's own interests and values[11]. The differential persistence of men and women in engineering has been attributed to differing levels of professional role confidence across genders, as women who feel mismatched with the culture of the engineering profession are less likely to develop a professional engineering identity and are consequently more likely than men to leave the engineering career path[11]. Yet the connections across and between *professional role confidence*, Everyday Examples in Engineering, and persistence within engineering majors are not fully apparent.

By adopting an active learning approach to teaching Engineering Statics, this study hopes to shed light on how student confidence is affected by the use of everyday teaching examples, with the intention of positively affecting student persistence in engineering. Two meaningful categories of everyday examples in engineering are proposed in the context of teaching statics: Body-Based and Traditional. Body-Based examples use the human body as the fundamental unit of analysis and use tangible sensation within the body to connect internal feelings to technical concepts, providing an internal experience of engineering expertise and knowledge creation. Traditional examples are those everyday examples more common to engineering and everyday life, including wrenches, clamps, trees, desk chairs, and other objects.

In fall 2012, the pilot year of study implementation, the following two research questions were among those examined:

1. Does the use of body-based vs. traditional examples affect student confidence?
2. Does the use of body-based vs. traditional examples affect student conceptual knowledge?

This paper presents the overall methodology and logistics for the study in its pilot year including details on approach implementation, examples of active learning lesson plans of both Body-Based and Traditional recitation tracks, and preliminary findings based on gross comparison of pre-/post- concept inventory and selected attitudinal survey categories.

Background

The details of course structure as well as samples of active learning lesson plans for both Body-Based and Traditional tracks are presented here. Notes on how recitations were implemented and adjusted during the semester for optimum student participation are also included in this section, along with details regarding the mixed-methods assessment strategy employed to measure student dimensions of interest both incoming and exiting the fall 2012 semester.

Course Structure

As a 3-credit course, Statics was scheduled for a biweekly 50-minute lecture and a 50-minute recitation period. Lectures met Monday and Wednesday, recitations at 3 different times on Friday. Student attendance at active learning recitation sessions was mandatory. Lectures were held in a large traditional style lecture hall and taught by an experienced professor who was up to the challenge of entertaining the 200 students enrolled in the course. The 200 students were split into six different recitation sections held at three different times, all on the same day (Friday), meaning that there were always two recitation sections concurrently occurring. Students self-selected their recitation times to optimize their schedule, then were randomly shuffled into one of the two sections offered at that time. The recitation sections were split evenly so that three sections utilized Body-Based examples, while the other three used Traditional examples.

Recitations were team-taught by pairs of undergraduate learning assistants and graduate teaching assistants, with each recitation instructional team administering both Body-Based and Traditional style recitations each week (for information on the learning assistant program and model, see reference 12). Additional implementation details can be seen in Figure 1.

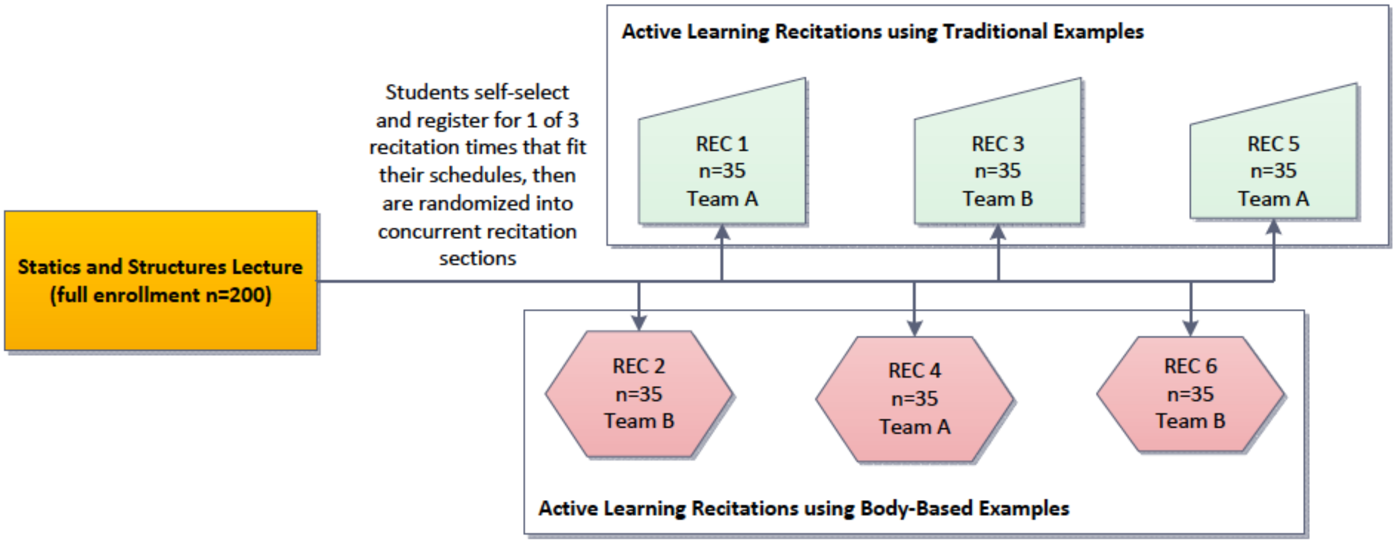


Figure 1: Fall 2012 Course Structure

The lecture portion of the course was conducted following the organization of Meriam and Kraige's *Engineering Mechanics: Statics 7th ed.* Textbook[13]. Homework assignments were assigned and collected weekly and included problems from the textbook as well as some homegrown problems. Two midterm exams and one comprehensive final exam were administered over the course of the 16-week semester. The overall grade breakdown for the course was 25% homework assignments, 30% midterm exams, 20% final exam, 5% recitation attendance, 15% recitation worksheets, and 5% for overall participation in the course. An optional 5% additional percentage was offered to students in exchange for participating in the research portion of the course (namely completion of consent forms, pre, and post-surveys), so that students who opted-in were given 5 additional percentage points and their final course grades were normalized out of a 105 point scale instead of 100.

Weekly recitations were structured in accordance with the *Engage Engineering – Everyday Examples in Engineering* initiative and employed the 5 E's as a template: engage, explore, explain, elaborate, and evaluate[6]. The *engage* step was used as an introduction to the day's recitation activity, and typically involved the instructors doing a physical demonstration, showing a brief video, reminding students of the week's topic, or asking students conceptual questions to discuss out loud. Then, recitation worksheets were distributed to the students in the class for the remaining stages of the lesson. A short, relatively simple, conceptual problem would take the front side of the worksheet as the *explore* step, and students were encouraged to work in small groups to solve the problem with instructors available for clues or help. The class would subsequently review the answers to the first part of the worksheet together, with instructors guiding and explaining concepts as necessary – the *explain* step. In the fourth *elaborate* step, students would complete the second part of the worksheet, typically a more complicated problem involving multiple steps or the integration of multiple concepts. The 50- minute recitation period would conclude with each student turning in a 3x5" notecard including name, department ID, and responses to a couple quick multiple choice questions, rating scales of conceptual understanding, or listing of muddy points for further clarification. These *exit ticket* notecards were the final *evaluate* step of the 5 E's, in this case focused on how students evaluate their own understanding of the material instead of any formative or summative assessment of student learning. Two selected samples of detailed lesson plans for both Body-Based and Traditional recitations are included in the following section of this paper.

The lesson plans for Body-Based and Traditional recitation sections were designed to mirror one another as closely as possible in format, difficulty, and problem statements, with the salient difference being the object under study in a given problem – one's own body or an external object. A summary comparison table of the examples used in Body-Based and Traditional recitation sections over the 15-week semester is appended in Table 5**.**

Detailed Lesson Examples

Looking in depth at the recitation lesson plans from week 6 and week 11 of the 15-week semester helps to further illustrate the active learning approach utilized, the salient differences between Body-Based and Traditional recitation sections, and the overall format of the recitations. The topic of week 6 was 3D Equilibrium systems, with the 5 E steps as explained below:

Week 6 – 3D Equilibrium Systems

1 – Engage – Remind students that their exam is coming up next Monday and will cover topics on 2-D equilibrium and 3-D force systems. Today they will once again be coming up with examples for each type of end condition. Emphasize they are NOT drawing free body diagrams, instead they are looking at the forces applied to the object being isolated at that specific end condition (as it is the book). Instructors will give 1 example for the 1st end condition (member in contact with smooth surface) to get the students started.

2 – Explore

Students will be provided with the 1st column of the table on page 147 (Modeling the action of forces in three-dimensional analysis), and asked to sketch their own real world examples of each type of contact and force origin. Then, they will be required to draw FBDs for each situation. Encourage students to compare and contrast with their examples from a few weeks ago – how does going to 3-D change their table?

3 – Explain

Help students as needed to get examples down for each example.

4 – Elaborate

Once students are done with the table of examples, they will move on to solving a problem with a robotic arm/human arm as shown on the worksheet.

5 – Evaluate

Exit tickets this week will include:

*Name

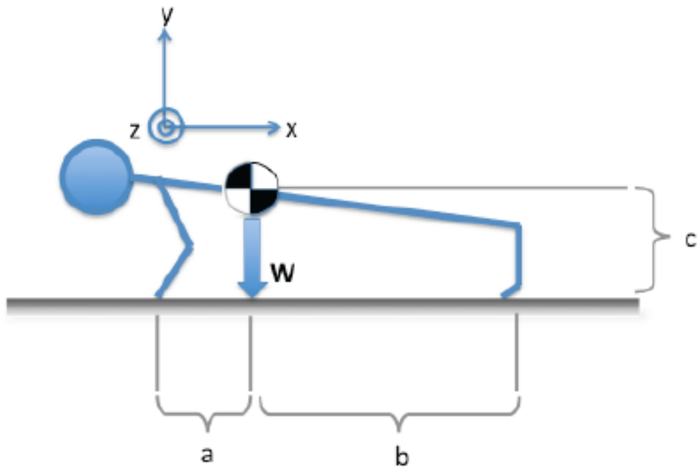
*ME-ID

*Feeling about upcoming exam (1 – relaxed, 2 – a little nervous, 3 – ambivalent, 4 – somewhat stressed, 5 – very stressed)

*Are you planning to attend Statics review session this Sunday? (Y/N)

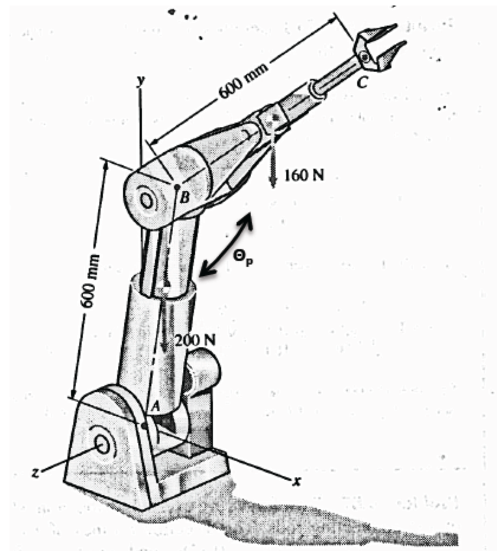
* Would you expect to see a problem like the one posed in this recitation on your exam?

The worksheets for the Body-Based and Traditional sections for week 6 were identical with the exception of the last problem, a 3-D robotic arm vs. a 3-D human arm. The illustrations and the first part of the problems are provided in Figure 2 below.



A) The person doing push ups pauses in the position shown. Her mass is 65kg. Assume that the weight W acts at the point shown. The dimensions are a=250mm, b=740mm, and c=300mm.

1) Determine the normal force exerted by the floor on each hand.
2) Determine the normal force exerted by the floor on each foot.



A) The robotic manipulator is stationary. The weights of the arms *AB* and *BC* act at their midpoints (200N and 160N, respectively). The direction cosines of the centerline of arm *AB* are cos θ_x = 0.500, cos θ_y = 0.866, cos θ_z = 0 and the direction cosines of the centerline of arm *BC* are cos θ_x = 0.707, cos θ_y = 0.619, cos θ_z = -0.342.

1) What total moment is exerted about the *z* axis by the weights of the arms?

Figure 2: Week 6 Problem Image and Part A Problem Comparison, Human vs. Robotic Arm[14]

The topic of week 11 was distributed loading and modeling a distributed load as a point load in order to solve an equilibrium problem. A classic biomechanics lab using the reaction board technique to calculate center of gravity (CG) was adapted for use in the active learning statics recitations[15]. The Body-Based recitation sections used the reaction board to calculate the location of their own body's CG in varying positions while the Traditional recitation sections used the reaction board to calculate the location of the CG for everyday objects including a desk lamp, hammer, cordless drill, and ski boot. The 5 E's for week 11 are below:

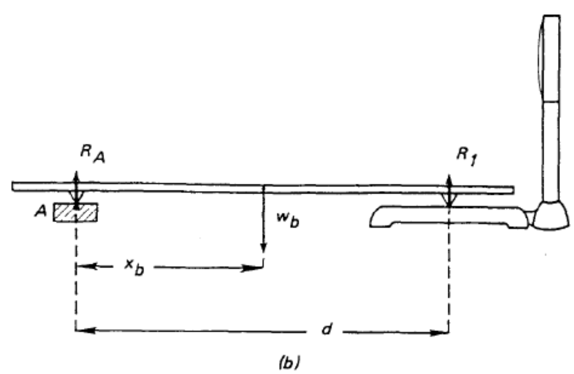


Figure 3: Reaction Board Diagram[15]

Week 11 – Solving Problems With Distributed Loading

1 – Engage

One direct method of calculating the CG involves a device known as a reaction board. The reaction board consists of a long rigid board, which is supported as each end on "knife edges" (see Figure 3). Under one end of the board is a scale. The other end is simply elevated such that the board is level.

For the engage step – ask students to draw the FBD of the board, scale, and elevated point setup as is.
Solve for the sum of the moments about A (leave in symbolic form – the 2 steps below).
$\Sigma M_A = 0$
$\Sigma M_A = (R_1 d) - (w_b x_b) = 0$
Then, pass out the worksheets.

2 – Explore

Before doing experimentally – students will draw the relative distributed loading of bodies in different configurations (traditional will draw the relative distributed loading of different everyday objects). Then, they will draw the free body diagram for the situation in which the reaction board is loaded with a person or object's weight. Students will write the equations to solve for unknown distance *x* (from the endpoint A to the location of the person/object's CG).

3 – Explain

Review the equations with the class. Should look something like:
$\Sigma M_A = (R_2 d) - (Wx) - (w_b x_b) = 0$
From Part 1, the unloaded board, we know that $(R_1 d) = (w_b x_b)$
By substitution, $(R_2 d) - (Wx) - (R_1 d) = 0$
And as a result $x = \frac{(R_2 - R_1)}{W} * d$
Note that this expression for x does not have any relation to x_b, the distance to the board's center of gravity. This information is unnecessary as it is accounted for in R_2 and R_1.

Body-Based: Take a student volunteer to lay on the board, and have the class record data for scale readings in the following situations:

0) Board with no load (Figure 3)
1) Board with person lying on it with arms by their sides (see worksheet)
2) Board with person lying on it with arms reaching up (see worksheet)
3) Board with person lying on it with both arms overhead (see worksheet)
4) Board with person sitting up on it (see worksheet)
5) Others?

Traditional: Take a student volunteer to help with the experimental setup of placing objects on the board, and weighing them. Have the class record data for scale readings in the following situations:

0) Board with no load (Figure 3)
1) Board with desk lamp
2) Board with hammer
3) Board with drill
4) Board with ski boot
5) Others?

4 – Elaborate

Students will make predictions about which of the situations (#1-4 above) will have the highest/lowest CG (or distance x), and why. What does this mean about distributed loading?
Then they will solve for the unknown distances x.

5 – Evaluate

Exit tickets this week will include:
1. Name + ME-ID
2. Confidence Level on learning objective (1 – not confident, 5 – confident)
3. Conceptual questions for wiki FAQ?
4. Comments on the reaction board method.

In week 11, both Body-Based and Traditional recitation sections used the reaction board method to calculate the location of an unknown center of gravity. The bulk of the experimental setup as well as the student learning activities and calculations were identical, with the only difference being the example under study (a human body vs. an everyday object). Students were asked to first sketch the relative magnitude of the distributed load for each object/each body position, draw a free body diagram to represent the reaction board technique, and then solve the equilibrium equations for the reaction board to calculate the distance from one end of the board to the location of the object/body position's CG.

Mid-Semester Course Changes

Several logistical changes were made mid-semester in order to facilitate increased student participation in the recitation activities. For the first 7 weeks of the semester, students were encouraged to work collaboratively in teams and turn in one worksheet per group for a completion grade. Unfortunately, some students took advantage of this recitation structure and did not participate actively in the group learning activity because they assumed that one of their group members would do the work and turn in the worksheet with their names on it. To alleviate this, a change was made to require all students to turn in a worksheet for each recitation. As some students were stressed by having only the 50-minute class period to finish and turn in their worksheet, the due date for recitation worksheets was changed from immediately following recitation to close of business on the next working day. To facilitate the completion of the worksheets without adding undue stress or additional homework on the students, solutions/sample answers to both Body-Based and Traditional recitation problems were posted online following the recitation section meetings, but prior to the due date for that week's recitation worksheets, for students to reference as necessary.

Following week 7 of the semester, the recitation instructor pairings were rearranged in order to optimize the teaching partnerships for both teams. Initially both teams of recitation instructors consisted of one graduate teaching assistant and one undergraduate learning assistant, and one female and one male. Midway through the semester, the two male instructors switched partners, so that both teaching partnerships were still mixed-gender but now one of the instructional teams included both undergraduate learning assistants while the other instructional team included both graduate teaching assistants. The change did not noticeably affect students in the recitation sections while benefiting the interactional dynamics between the recitation instructors.

Research Method

The assessment of this dual-track active learning approach utilized a mixed-methods sequential explanatory design, with initial quantitative data informing subsequent qualitative data collection, followed by a final quantitative stage[16].

A graphical depiction of the assessment scheme is available in Figure 4, including emphasis on how the analysis and findings from each stage of data collection inform one another. The initial quantitative stage included the Force Concept Inventory (FCI), administered online via cihub.org as well as an initial online attitudinal survey including items related to community and belonging, engineering identity scales, emotional affect ratings, professional role confidence survey items, selected Academic Pathways of People Learning Engineering Survey (APPLES) categories, and selected measures of student engagement borrowed from the National Survey of Student Engagement (NSSE)[11, 17–24]. The intermediate qualitative stage included observational fieldnotes of lectures as well as recitation sections throughout the semester, and one-on-one interviews with eleven focal students conducted during weeks 11 and 12 of the 16-week semester. The focal students were selected to represent a variety of demographics with regards to race and gender, and were chosen so that all Body-Based and Traditional recitations, instructional teams, and meeting times were represented as well. The interview protocol was semi-structured and included items relating to student background, motivations for studying engineering, feelings of belonging and identity within engineering, and opinions and experiences specifically related to the statics course and overall course load during fall 2012. The final quantitative stage of data collection included the Concept Assessment Tool for Statics (CATS) administered online via cihub.org as well as an outgoing attitudinal survey that included a subset of survey items from the incoming survey with the addition of items related to student experience in the fall 2012 statics course and survey items adopted from the Conceptions of Learning Engineering (CLE) Survey[25-26]. Students were required to complete both FCI and CATS as part of their course participation grade, though their performance on these assessments was not linked to their grades.

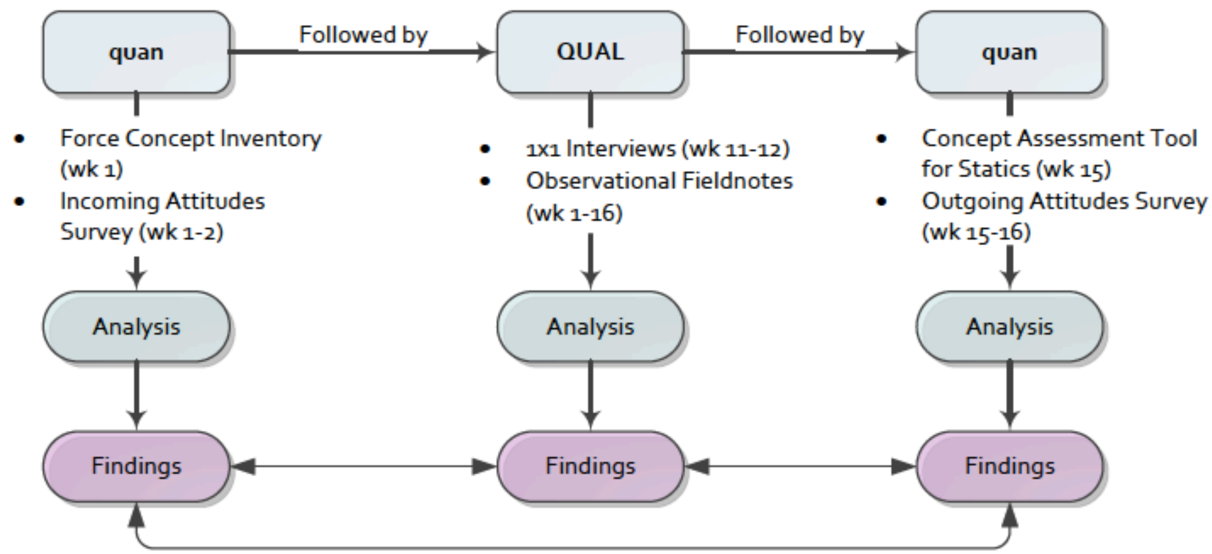


Figure 4: Mixed-Methods Sequential Explanatory Design

Preliminary Findings

Changes in conceptual knowledge were measured roughly by comparing the scores on the incoming Force Concept Inventory (FCI) with the scores on the outgoing Concept Assessment Tool for Statics (CATS). Descriptive statistics for each test overall were calculated based on the cohort of students who fully completed both the FCI and the CATS. While 189 out of 200 students created accounts on cihub.org to take the FCI and 180 out of 200 students logged into their accounts to take the CATS, only 160 full data sets existed (some students did not complete the FCI or CATS, some students took only the FCI or only the CATS). The mean and variance for student performance on the FCI and CATS can be seen in Table 1.

Table 1: Mean and Variance comparison, FCI and CATS (# observations = 160)

FCI (Pre)		CATS (Post)	
Mean	Variance	Mean	Variance
71.5%	0.030	49.9%	0.045

There was a significant decrease in average student performance on the concept inventories from pre- to post-. The approach of using the FCI as an incoming concept inventory and the CATS as an outgoing concept inventory assessment is strongly advocated by the creator of the CATS as students are not expected to have knowledge of Statics before taking the course[27]. Success on the FCI is theorized to predict success on the CATS for individual students[27], though the data is analyzed in the gross aggregate here and does not display individual effects. The change in means (Δ -0.216) is offered for reference, subsequent detailed data analysis is saved for future work.

Further statistical tests were performed comparing the concept inventory scores of the Body-Based cohort with the Traditional cohort on both the incoming FCI and the outgoing CATS. The results of Two-Sample Assuming Equal Variance Student t-Tests can be seen below in Table 2. No statistically significant differences can be seen in the scores on the concept inventory between the two groups on either the FCI (p=0.507) or CATS (p=0.321). The average score for the Traditional cohort on both the FCI and CATS was slightly greater than the Body-Based cohort (FCI: Traditional mean=72.4% Body-Based mean=70.6%, CATS: Traditional mean= 51.6% Body-Based mean=48.2%), but not to a statistically significant degree.

Table 2: Two-Sample assuming Equal Variances, Comparison of Body-Based and Traditional (degrees of freedom = 158)

	Body-Based		Traditional		Change in Means, Body-Based and Traditional	T-test: Two-Sample assuming Equal Variances P(T<=t) two-tail
	Mean	Variance	Mean	Variance		
Pre-Scores (FCI)	70.6%	0.031	72.4%	0.029	0.018	0.507
Post-Scores (CATS)	48.2%	0.053	51.6%	0.037	0.033	0.321

A subset of items from pre- and post- attitudinal surveys were selected for preliminary analysis: four categories of confidence, as defined by APPLES and the concept of Professional Role Confidence[11, 23]. These include confidence in solving open-ended problems, confidence in math and science skills, expertise confidence (the first component of professional role confidence), and career-fit confidence (the second component of professional role confidence). All questions consisted of 5-point Likert rating scales with "I prefer not to answer" as a sixth optional response, and were phrased identically on pre- and post- surveys. Individual survey items by category grouping are available in Appendix A. Similar to the analysis of the concept inventory data, descriptive statistics for each of the confidence categories were calculated overall and within-samples paired t-tests were performed based on the cohort of students who fully completed both the pre- and post- attitudinal surveys. The data shown were taken from the original 5-point Likert scale, normalized and converted to 0-1.00 for the sake of reporting (e.g. 0 corresponds with all 1's or low ratings for that category, 0.5 corresponds with all 3's or middle ratings for that category, 1.00 corresponds with all 5's or high ratings for that category). 190 out of 200 students completed the Pre-Survey, while 163 students completed the Post-Survey, resulting in 152 complete datasets (some students completed the Pre-Survey who did not take the Post-Survey, and vice versa). The results of Paired Two Sample for Means Student t-tests on that dataset can be seen in Table 3.

Table 3: Paired Two-Sample for Means, Comparison Pre- to Post- on Confidence Items (# observations = 152)

	Pre-Survey		Post-Survey		Change in Means, pre- to post-	T-test: paired 2 sample for means P(T<=t) two-tail
	Mean	Variance	Mean	Variance		
Solving Open Ended Problems	0.760	0.017	0.718	0.020	-0.042	1.77E-04
Math/Science Skills	0.741	0.019	0.717	0.023	-0.024	5.80E-02
Expertise	0.752	0.032	0.638	0.045	-0.115	4.73E-10
Career-Fit	0.729	0.046	0.667	0.046	-0.062	1.88E-04

All categories showed statistically significant decreases in average level of student confidence from pre- to post-. The most dramatic change occurred in the category of Expertise Professional Role Confidence (Δ -0.115), followed by Career-Fit Professional Role Confidence (Δ -0.062), Confidence in Solving Open Ended Problems (Δ -0.042), and finally Confidence in Math/Science Skills (Δ -0.024). While all differences were found to be statistically significant, the greatest statistically significant difference was seen in the category of Expertise Professional Role Confidence, followed by Confidence in Solving Open Ended Problems, Career-Fit Professional Role Confidence, and Confidence in Math/Science Skills.

Additional statistical tests were performed comparing the confidence category scores of the Body-Based cohort with the Traditional cohort on both incoming and outgoing attitudinal surveys. The results of Two-Sample Assuming Equal Variance Student t-Tests between the two cohorts can be seen below in Table 4. No statistically significant differences were found in comparing Body-Based to Traditional groups in any of the confidence categories on either the incoming or outgoing attitudinal survey.

Table 4: Two-Sample Assuming Equal Variance t-tests, Comparing Body-Based to Traditional in Incoming and Outgoing Confidence Categories (degrees of freedom = 150)

		Body-Based		Traditional		Change in Means, Body-Based to Traditional	T-test: Two-Sample assuming Equal Variances P(T<=t) two-tail
		Mean	Variance	Mean	Variance		
Solving Open-Ended Problems	Incoming	0.754	0.018	0.767	0.016	0.013	0.548
	Outgoing	0.719	0.020	0.717	0.020	-0.001	0.949
Math/ Science Skils	Incoming	0.747	0.016	0.734	0.023	-0.013	0.575
	Outgoing	0.717	0.022	0.717	0.025	0.001	0.983
Expertise	Incoming	0.755	0.030	0.749	0.035	-0.006	0.831
	Outgoing	0.649	0.042	0.624	0.048	-0.024	0.484
Career-Fit	Incoming	0.745	0.041	0.709	0.052	-0.035	0.312
	Outgoing	0.692	0.042	0.636	0.050	-0.056	0.108

Discussion

Data from the pilot year displays statistically significant decreases from the incoming Force Concept Inventory (FCI) to the outgoing Concept Assessment Tool for Statics (CATS). This does not correlate with an overall decrease in conceptual knowledge, as these two concept inventories measured separate sets of concepts. These results could be interpreted to mean that students generally had higher comprehension of the topics on the FCI than on the CATS, despite taking a full semester of the Statics course; or the students could have tried harder on the FCI than the CATS (or vice versa) as they are not graded for their performance on these assessments, just completion. The results from fall 2012 can be compared to national measures of performance on the FCI and CATS to further understand how this year's cohort compares to others, both past and future, and has been noted for future work.

Statistical tests showed no significant differences between the performances of students in Body-Based vs. Traditional recitation sections on either the FCI or the CATS. The lack of difference between the two cohorts on the FCI indicates that at the start of the semester, the two groups were comparable in their level of incoming conceptual understanding. On the other hand, the lack of difference between the two cohorts on the outgoing CATS shows that by the end of the semester, the use of different context for examples had little to no impact on resulting student conceptual knowledge. Students had similar levels of outgoing conceptual knowledge regardless of if they learned through internal body-based or external object-oriented examples during the semester in recitation.

Analysis of the four confidence categories chosen for preliminary study demonstrates average decreases across the board in all four categories from the time students entered the course and took the pre-survey to end of the semester when the post-survey was administered. While it is not an optimistic finding, further investigation and analysis of qualitative data could shed light on other factors affecting student confidence aside from Statics during the fall 2012 semester. As most of the students in the course were traditional sophomores at the time of taking Statics, it was truly a gateway course in the sense that it was the first time students were asked to think as an engineer and solve problems using a methodical engineering approach. The class emphasized real-world problems and the class occasionally struggled with difficult real-world examples, perhaps contributing to the decrease in the APPLES category of confidence in solving open-ended problems[23]. It is possible that the initial confidence in solving open-ended problems upon entering the fall 2012 semester was not based on much prior experience of actually solving open-ended problems, as the math and physics courses leading into the second year often have much more prescribed problem statements and algorithmic approaches to problem-solving than the more creative analytical approaches encouraged in Statics.

Confidence in math/science skills was another APPLES category that demonstrated statistically significant decreases from pre- to post- participation in Statics[23]. This change is not altogether surprising as the sophomore year increases considerably in difficulty from the first year curriculum, and, unlike the first year curriculum, there is no fun and hands-on “freshman projects course” in the second year to encourage students in their engineering abilities. The sophomore and junior year of this and most other 4-year engineering undergraduate programs are known for technical rigor, which can discourage and diminish feelings of student confidence in math/science skills. The trends shown in this dataset indicate that student confidence in math/science skills already decreases after just the first semester of the sophomore year; it would be interesting to see if confidence continues to decrease through the end of the sophomore year and junior year, or if it gets to a low point and remains there after the first sophomore semester. It is also important to note that the students took the post-survey during finals week of 2012, when stress levels are unavoidably high, and self-perceptions of skills or confidence may have been underrated.

High levels of student stress while taking the post-survey could have also affected the observed decreases in the two types of Professional Role Confidence, Expertise and Career-Fit confidence[11]. As Expertise confidence is the confidence in one’s ability to possess the skills and expertise necessary for engineering practice, it could have decreased for similar reasons that the confidence in solving open-ended problems or confidence in math/science skills decreased during the course of the fall 2012 semester. Career-Fit confidence, or the confidence that an engineering career path is well matched to one’s own interests and values, showed a statistically significant decrease from pre- to post- participation in Statics perhaps due to increased learning about the engineering discipline and the actual practice of engineering during fall 2012. As Statics is the gateway course to engineering, it also possible that students who disliked Statics and did not enjoy their experience in the class consequently felt that the engineering career path (including Statics) was not matched to their own interests and values, or their future interests and values. If so, this is unfortunate and not a desired outcome of participation in the course.

The lack of statistical difference between Body-Based and Traditional cohorts was observed across all four confidence categories on both pre- and post-surveys. This indicates that to begin with, the students in the Body-Based and Traditional recitation sections were comparable and not statistically distinct. By the end of the semester, the lack of statistical difference between Body-based and Traditional cohorts indicates that there was little impact on students’ confidence as a result of the different types of learning examples used in the recitation classrooms. This data shows that using internal body-based examples and external object-based examples have little to no effect on student confidence levels, it is entirely possible that engineering student confidence is not connected to what types of examples are used to teach engineering subjects like Statics.

Conclusions

Perhaps the most surprising finding from the pilot year of this study was that students generally struggled and disliked any ambiguity or uncertainty when facing real-world problems or examples in recitation, on their homework assignments, or during lecture. The qualitative data from both from classroom observations and in person interviews makes this clear, as students frequently had negative emotional responses when faced with problem statements that were not completely defined, or "well-defined" in the eyes of the students. Students commented that they felt the textbook was sufficiently real-world, indicating that what students see as "real" may be very different from the way engineering instructors and engineering education researchers define "real" or "real-world". Few differences, if any, were observed in student reactions to Body-Based vs. Traditional recitation examples, as generally students were perturbed by real-world examples regardless of being internally body-centered or externally object-oriented.

Future Work

As analysis of the data from the pilot year continues, additional comparisons and statistical tests will be run between Body-Based and Traditional cohorts to determine if the types of examples used had any differential effects of significance on the students. Furthermore, scores on APPLES scales including the confidence categories of open-ended problem solving and math/science skills will be compared to national data from prior administration of APPLES at other institutions around the US. Similarly, comparable populations of young engineering students that have been surveyed on the axes of Professional Role Confidence will also be sought for comparison to better understand if the statistical differences and changes pre- to post- observed here are typical or atypical of undergraduate engineering students. Additionally, the performance on the CATS from fall 2012 will be compared to seven years of existing in-house data from past administrations of the CATS on outgoing cohorts of students.

The results from Body-Based and Traditional cohorts will also be split by gender and ethnicity, then compared to see the presence or absence of any differential effects in these populations of interest. Additional factors to be considered include time of day of recitation, recitation instructors, incoming/outgoing GPA, etc. There are yet many more statistical analyses to be performed with the quantitative data.

Detailed comprehensive analysis of the qualitative portion of the data collected will also help to better understand how much Statics in particular affected student changes in confidence levels as opposed to the rest of the students' course load in fall 2012. Qualitative data will be transcribed and coded using a mixed inductive/deductive coding scheme to find trends and similarities in student experiences across the fall semester. The findings from the qualitative data will inform the findings from the quantitative data and vice versa, as the research team works to understand how to improve the course offering for future implementations and how to better support young engineering students as they pass through the gateway of Statics.

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Appendix A: Confidence Categories and constituent survey items

APPLES Confidence in Math and Science Skills[23]

Confidence: Science ability
Confidence: Math ability
Confidence: Ability to apply math and science principles in solving real world problems

APPLES Confidence in Solving Open-Ended Problems[23]

Creative thinking is one of my strengths
I am skilled at solving problems with multiple solutions
Confidence: Critical thinking skills

Professional Role Confidence: Expertise Confidence[11]

As a result of my engineering courses:
Developing useful skills
Advancing to the next level of in engineering
My ability to be successful in my career

Professional Role Confidence: Career-Fit Confidence[11]

As a result of my engineering courses:
Engineering is the right profession for me
Selecting the right field of engineering for me
Finding a satisfying job
My commitment to engineering

Table 5: Summary Comparison of Traditional and Body-Based Recitation Examples

Week/Topic	Traditional Recitation Examples	Body-Based Recitation Examples
1 – Vector Review	• Icebreaker and team building	• Icebreaker and team building
2 – 2D Force Systems	• Incline Plane • Spinning Plate • Couples in Mechanisms	• Simple Balancer • Moments in the Body • Couples on a Chair
3 – 2D Equilibrium, Part 1	• Brainstorm 2D Contact Examples • Broken Lecture Hall Desks	• Brainstorm 2D Contact Examples • Common Injuries in Snowsports
4 – 2D Equilibrium, Part 2	• Create, Swap, and Solve Statically Determinate and Solvable 2-D Equilibrium Problem	
5 – 3D Force Systems	• Leonardo DaVinci's Cam Hammer • 3D Moments in Toys	• 3D Coordinate system in the body • 3D Moments opening a Jam Jar
6 – 3D Equilibrium	• Brainstorm 3D Contact Examples • Robotic Arm 3D Equilibrium Problem	• Brainstorm 3D Contact Examples • Push-Up (human arm and shoulder) 3D Equilibrium Problem
7 – Trusses, Method of Joints	• Craft Stick Pin Joint to illustrate compression/tension	• Squeezing/pulling a racquetball through the forearms to replicate a joint
8 – Trusses, Method of Sections	• Santa on roof as point load	• Weightlifter with barbell as point load
9 – Frames and Machines	• Folding Chair (multiforce members)	• Human multi-force arm with bicep and tricep in tension
10 – Centroids	• Centroid of snow load • Snow Load on Minneapolis Metrodome	• Centroid of your own body • Centroid of human head model
11 – Distributed Loading	• Reaction board: distributed loading of everyday objects	• Reaction board: distributed loading of your own body
12 – Review for Exam #2	• Conceptual Review Game	• Conceptual Review Game
13 – no class		
14 – Friction	• Friction Predictions, box on incline plane with varying friction angle	• Friction Predictions, person on incline plane with varying friction angle
15 – Review for Final exam	• Conceptual Review Game	• Conceptual Review Game