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Standardizing the Statics Curriculum Across Multiple Instructors

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Abstract

At the Florida Institute of Technology, multiple sections of Statics are offered each fall semester, each taught by a different instructor. Though all sections cover the same topics within the same textbook, students often perceive the course sections differently. Different combinations of online and paper homework formats were used, and the problems assigned varied in volume, implementation, and complexity. In each section, different pedagogies were used, and the depth to which some topics were covered varied with the instructor. Because each section took different exams graded by different instructors, there was no uniform measure of students' preparedness levels for later engineering mechanics courses. This paper describes efforts to improve consistency across sections by implementing a common course framework developed by the instructors teaching the different sections. This framework includes common online and on-paper homework assignments, and a common final exam with a communal grading strategy where all students, regardless of section, had their problems graded by the same instructor. Though each faculty member was free to employ different pedagogies within the common framework, all made a commitment to increase active learning strategies in the classroom. Student perceptions of the common framework were obtained using an end-of-course survey, and student performance on the common final exam and a basic skills test were compared across sections. Instructor perceptions about the challenges and benefits of moving towards commonality are also discussed.

Introduction

Statics at Florida Tech is a three-credit course taught by both Mechanical Engineering and Aerospace Engineering faculty. Three sections are typically offered in the fall, and students are a mix of engineering majors. Students select their own sections based on schedule availability and personal preference, often influenced by perceived variations across sections.

The three instructors teaching statics during the Fall 2017 semester decided to work together to establish more consistency in course expectations, to share best practices, and to attempt to quantify student learning across sections. The goal was to improve student learning and to address student perceptions about some sections being more difficult than others. If students perceived that expectations were consistent and fair, this might reduce student preference for particular sections and provide administrative benefits, including reducing overhead associated with student requests to change sections and keeping class sizes more uniform. It was also hoped that by improving consistency and sharing outcomes- what was working, what was not- all students would do better and have an increased appreciation for the importance of statics as the foundation for future engineering classes.

For the Fall 2017 semester, Statics Sections 1 and 2 met three times a week for 50 minutes; Section 3 met twice a week for 75 minutes. Prior to the semester, the instructor team agreed upon course flow, timing and content of exams, the relative weighting of exams and homework, a common homework grading rubric, and which homework problems would be assigned. During the semester, the instructor team met weekly to discuss course flow, student progress, and efforts to include more active learning in the classroom. At the end of the semester, the instructor team developed and shared in the grading of the common final. At the end of the course, students in all sections completed an anonymous survey gathering information on their experience in statics during the semester.

Implementing Common Online and On-Paper Homework

Studies have shown that homework is a powerful tool for learning, especially homework that is graded [1], [2]. The statics instructors agreed that weekly homework would be worth 15% of the total grade, and problems would be drawn from the course text, Engineering Mechanics: Statics, 14th edition, by Hibbeler [3]. Prior to Fall 2017, two of the three instructors had never used online homework before, instead relying on paper assignments hand-graded by graduate students. For two previous classes, the third instructor had used a mix of paper assignments and online problems using Pearson's Mastering Engineering system [4]. The group decided to adopt this mix for Fall 2017 and give equal weighting for online and on-paper assignments. After some debate about how many online problems should be given each week, problems were selected and the system was set up for the semester.

The decision to use a mix of online and traditional on-paper homework was motivated by a desire to balance what is best about both formats. Traditional on-paper homework provides an opportunity for corrective feedback, and allows the student a chance to practice a structured approach to problem solving and presentation of technical work. The instructors developed a common rubric for the on-paper homework that stressed both areas, stating… "A solution is only as good as the manner in which it is communicated… [and] the correctness of any solution can only be judged after evaluating the solution process with its underlying assumptions." On the other hand, grading paper homework and providing detailed feedback for sections that may contain 50 or more students is time-consuming and costly, and feedback is typically delayed. Some studies have shown homework grades do not correlate well with exam grades [5], [6], possibly because some students rely excessively on online solutions and peers when completing homework problems [7].

The problem of students copying from online sources is pervasive [7] and not just an issue for standard problems from popular textbooks. In 2016 one of the authors created an all-new statics problem on aircraft center of gravity using an adapted image from an FAA website, and within a week the solution was available online for copying. The instructor was alerted to this fact because the online solution included a calculation error that appeared on 5 of 50 student papers, even though the syllabus prohibited the use of online resources to complete homework. Experiences like this make one question if customized paper homework is worth the significant effort involved.

Online homework reduces the grading load associated with teaching a course, provides immediate feedback to the student, and if the system includes the ability to randomize parameters in the problem, may make it somewhat more difficult to copy online solutions [8]. The most common student complaint about online homework is that these systems identify when a numerical solution is incorrect, but do not identify what is wrong; students also would like more hints on how to solve the problem [6]. Research reports mixed results on whether online vs on-paper homework provides greater benefits [9], [10].

Implementing a Common Final Exam and Basic Skills Pre/Post Quiz

At Florida Tech, statics exams are on-paper problems that are hand-graded by the instructor, with partial credit awarded for work shown. All sections gave three in-class exams and one common final exam. In-class exams could not be given at the same time and were not identical across section out of concern for cheating across sections, but the instructors coordinated to make them similar in scope and difficulty. For each in-class exam, each instructor also posted three different examples of past exams (one from each instructor) for the students to use for exam preparation. This provided a more uniform set of resources for the students to prepare for the exam, as well as increase the familiarity of all students to each instructor's exam question style that would be used for the common final exam.

All statics sections took an identical "common" final exam at the same time worth 25% of the course grade. Each instructor contributed and graded a proportional share of the problems for all sections. In Fall 2017 three instructors were teaching statics, so the exam consisted of three stapled sets of problems. Immediately after students completed the final exam, instructors met and traded sets so each had one-third of the exam to grade for all three sections. This common approach ensured that all students received the same point deductions for errors and the same partial credit for a given problem, and made the final exam scores a good measure of the learning gains in each section.

Students in all sections took a basic skills quiz at the start of the semester to sample student proficiency with trigonometry, geometry, units, and vector skills such as defining a position vector and computing dot and cross products. The same material was covered as part of the common final and results were compared to measure learning gains. Average GPA in each section was also collected and compared with scores for both the common final and "before and after" test.

Student Survey Participation Rates and Results.

After the students completed their common final exam, they took an anonymous survey to provide feedback on their statics experience. Surveys were completed by 151 students in three sections- a response rate of 87.3%, with good distribution across sections (Table 1). Extra credit on the homework grade was awarded for survey completion, which helped participation rates.

Table 1. Student Survey Participation Rate

	Surveys completed	Section size	Section participation	Percent of total respondents
Section 1	61	69	88.4%	40.4%
Section 2	35	49	71.4%	23.2%
Section 3	55	55	100.0%	36.4%
TOTALS	151	173	87.3%	100.0%

Self-reported student hours on class and homework

As seen in Table 2, total time spent on statics varied across section, and varied inversely with lecture time. Section 1, which had the greatest proportion of class time devoted to lecture, spent the least total time invested in class. Section 3, which was a hybrid flipped class, spent 1.5 hours more per week on class than section 1, presumably for classroom preparation. The average time spent on online and on-paper homework was similar across sections.

Table 2. Statics Activities: Hours spent by students (self-reported in survey)

	Statics: Total hours (class prep, class time, homework, study, etc.)	Average hours: online Statics homework	Average hours: on-paper Statics homework	Average hours: all Statics homework
Section 1 Average	5.9	2.6	1.8	4.4
Standard Deviation	3.7	1.2	1.0	
Section 2 Average	6.3	2.7	1.6	4.4
Standard Deviation	3.1	1.2	0.8	
Section 3 Average	7.5	3	1.7	4.7
Standard Deviation	5.3	1.5	1.0	
Semester Average	6.6	2.8	1.7	4.5
Standard Deviation	4.3	1.3	1.0	

Student perceptions of homework commonality

Almost 91% of students surveyed believed that the homework problems provided the necessary practice for topics covered on the exams, and most understood that homework was common across sections. Of the 151 students who completed the survey, only 7% of the students thought they had either more or less frequent homework; 63% of students thought all sections had the same homework frequency, while approximately 30% reported not knowing (Figure 1). Approximately 20% thought there were some differences in homework difficulty (Figure 2).

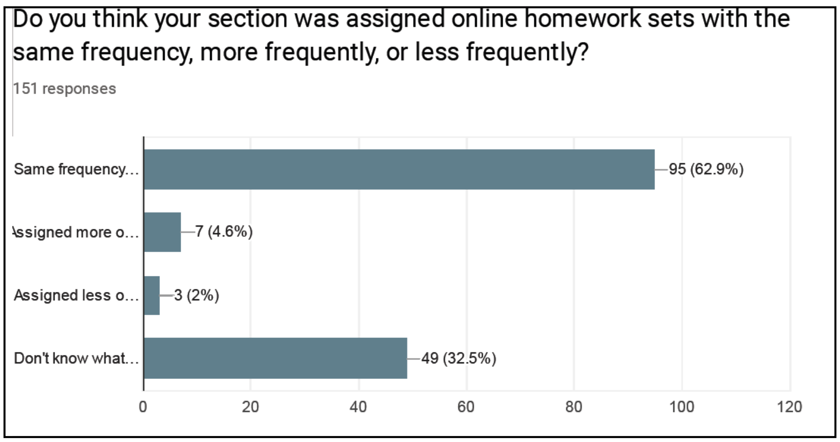

Figure 1. Student Perceptions of Homework Commonality (frequency)

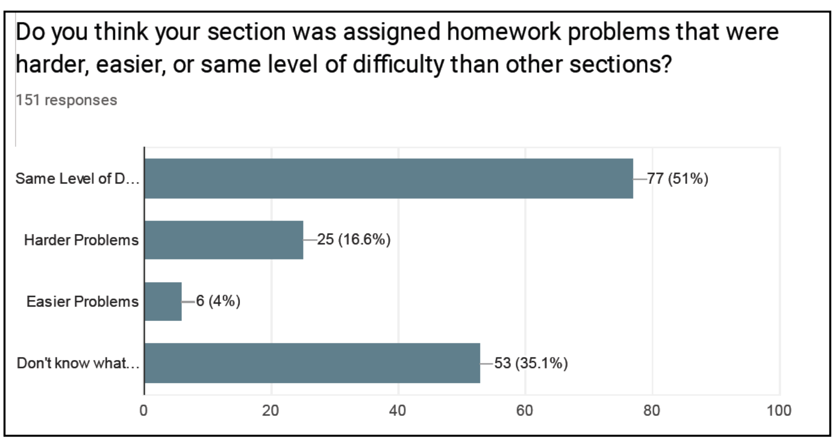

Figure 2. Student Perceptions of Homework Commonality (difficulty)

One factor in the perceived variations may have been a hurricane which briefly closed the school. This storm delayed some classes and put Section 3, which met twice a week on Tuesday and Thursday, slightly ahead of the others for a short period in the middle of the semester.

Student attitudes about Pearson's Mastering Engineering online system were of particular interest to the instructors who had not used online homework before. As seen in Figure 3, 60% of students found the immediate feedback helpful, and student survey comments suggested that the biggest benefit of the immediate feedback was general awareness- by letting them know they had made a mistake, they had a chance to self-diagnose what went wrong (typical response: "If I got it wrong, I could go back and figure out where"). In response to the question, "What actions did you take to improve your understanding of course concepts after receiving feedback from the on-line homework?" students reported reworking the problem, using the book or online educational videos to study the material more, reviewing similar problems to understand the steps involved, seeking help from a professor or tutor, and going online to find answers to the same problem or a similar one. One feature of Mastering Engineering is that some problem parameters can be randomized to prevent students from directly copying from each other or from the textbook solutions that are available online.

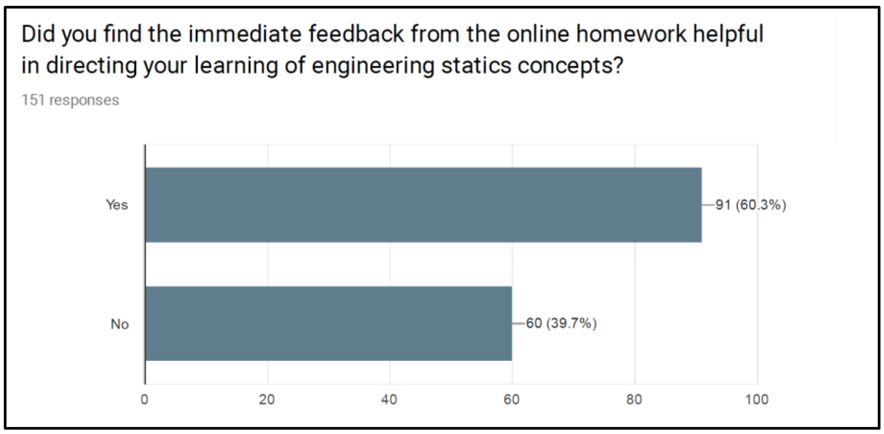

Figure 3. Online Homework: Usefulness of immediate feedback

Several students wanted Mastering Engineering to show the solution steps of the problem- not just the final result. Hints were also considered desirable.

- *"Online homework does not give feedback. It would online provide the correct answer but not the steps to get to that answer."*
- *"Allow for the student to view the correct answers and solution steps via the online homework, once the question has been completed or the student has "given up."*
- *Mastering Chemistry has a "hint" section that is very helpful in working out problems.*

Mastering Engineering has an Adaptive follow-up, where students can be assigned additional problems if they do not score sufficiently well on the homework, but 67% of students surveyed did not use this feature. It has been reported that some students perceive the adaptive follow-up problems as punitive in nature [6], so the instructors adjusted the settings so most students on most assignments were not required to complete it. Comments by those who used the adaptive follow-up were generally negative.

Most students (64.9%) used online homework problems as a study resource for the exams. Multiple approaches were reported, primarily keeping a notebook and reviewing items online.

Student attitudes about active learning in different sections

Instructors in all sections incorporated some form of active learning in the classroom, and 71% students found these in-class activities and practice sessions helpful (Figure 4).

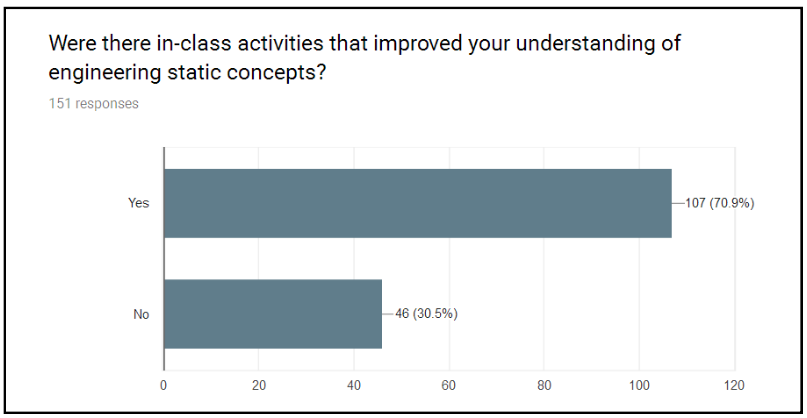

Figure 4. Usefulness of in-class activities / active learning

Section 1 was the most traditional of the sections, using primarily lecture slides and instructor – led problems with frequent instructor questions and multiple-choice problems on the slides. Some lectures were stopped for students to attempt problems immediately after concepts were introduced. After the class had some time with the problem, the instructor would complete it on the board. Visual aids were frequently used to tangibly illustrate concepts, and students were often asked to interact with visual aids- for example, pulling or pushing on rulers and bending flexible I-beams. Section 1 students also completed a group homework project- "Teams Teaching Statics"- where they had to create a visual aid and write a brief report on their attempts use it to teach a concept learned in class. In section 1, 70% of students reported that in-class activities were useful. In the comments section, 36% mentioned visual aids and hand-on activities as being the most helpful tool to aid learning, an observation that has been echoed in other research [11], [12].

Section 2 also used lecture slides and instructor-led problem solving, where each lecture included at least one problem that was worked interactively with the students, with the instructor asking the students questions to guide the solution approach and process. However, 6 class periods were dedicated to collaborative learning through student led group problem solving sessions with no instructor lecture. These class periods were based on collaborative learning technique known as “drill review pair” or “think pair squares” where students first work problems in pairs and then review the solutions in groups of four [13]. Sessions were strategically placed within the semester at the conclusion of chapter topics and to encourage class attendance. Teams were assigned by the instructor pairing students with stronger GPA and/or exam scores with weaker GPA/exam scores and applying the same strategy to grouping the pairs. Sessions were structured so that students imagined themselves working as engineers in the future assuming roles of a subject matter expert and a quality assurance engineer to form the initial pair and then grouped together as an engineering team to review a proposed solution. The instructor assumed the role of chief engineer and worked with pairs and teams to answer questions. At the end of the class period students submitted their work for participatory credit. The instructor would review the team’s submitted solutions and provide coaching on strengthening the necessary technical skills of the engineering team during the following lecture. Additionally, a fully worked out solution would be provided in the lecture notes. In Section 2, 74% of the students surveyed indicated these in-class group problem-solving sessions aided their learning.

Section 3 was a hybrid flipped class, where students were assigned readings and short videos to learn the fundamental material before class. A flipped or inverted course design requires students to watch videos, read materials, or complete basic assignments outside of the traditional lecture setting [14]. The instructor would do a brief review of the material covered that week, then most of the class time was reserved for group problem solving. Students worked in groups of three with hand-held white boards and the instructor would circulate through the class assisting groups as they worked through several pre-selected problems. Typically, class would consist of working through 2-4 increasingly complex problems. Once the majority of groups had either successfully completed or nearly completed a given problem, the instructor would quickly go over the problem with the entire class, focusing on aspects of the problem that gave the groups trouble. This format allowed the instructor to focus on what specific aspects of a topic the students were finding difficult. The difficulty with this approach is getting the students to come to class sufficiently prepared.

Fifty-eight percent of Section 3 students surveyed identified in-class activities as conducive to learning, but one lesson learned was that it was difficult for students to embrace the flipped teaching style if other options were available. Though flipped teaching can be a highly effective learning pedagogy, it requires more initiative from students, and student comments suggested many would prefer the path of least resistance. A representative comment: "*Don't take a professor who uses flipped classroom learning style. If they do, be prepared to put in a lot of work out of class.*" On the other hand, some students liked flipped teaching. One student comment: "*Be more active and independent on learning, instead of expecting to depend on classes and homework problems and be passive. Flipped class is definitely the most efficient way to learn Statics for any active student.*" There was not an explicit question addressing flipped teaching in the survey, but in Section 3, the ratio of favorable to unfavorable comments regarding the method was approximately 1:5.

Though active learning approaches were appreciated by the students in all sections, 85% also valued instructor-led examples in class (Figure 5). Write-in comments also highlighted those as very important to their learning.

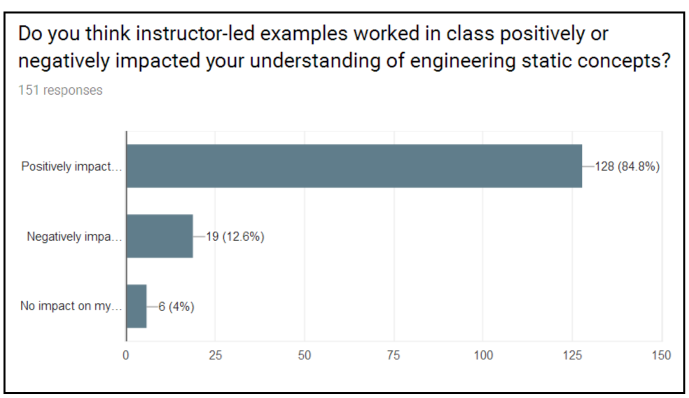

Figure 5: Perceived value of instructor-led examples

Results: Student performance across sections

Before and after data for the three sections are provided below for those students who took both the pre-test and the common final exam. A few students in each section did not take the pretest, and a few students that took the pretest dropped the class. Students improved proficiency in all sections to an acceptable level, with slight variations across sections tracking with GPA.

Table 3. Basic Skills Test: Scores before and after the class (Pre-test vs. Post-test)

	Section 1	**Section 2**	**Section 3**
Pre-test averages	60.1%	57.4%	68.6%
Pre-test standard deviation	14.9%	17.5%	16.5%
Post-test averages	86.6%	81.2%	84.6%
Post-test standard deviation	10.3%	15.3%	12.8%
Average student GPA	3.07	2.61	2.91

Grades for the common final exam grades are shown in Table 4. The Section 1 instructor graded problems 1.1 and 1.2 for all sections; the Section 2 instructor graded 2.1 and 2.2; and the Section 3 instructor graded 3.1-3.3.

Table 4: Student Performance on Final Exam -by problem

	1.1 Basic Skills Quiz	1.2 Truss Analysis	2.1 3D moment	2.2 Moment of Inertia	3.1 Internal Forces	3.2 Friction	3.3 Frame analysis	Final Exam Grade
SECTION 1 FINAL	SECTION 1 GRADES PER PROBLEM							
Percent Average	85%	72%	73%	86%	86%	83%	83%	81%
Standard deviation	12%	27%	23%	18%	18%	17%	18%	13%
SECTION 2 FINAL	SECTION 2 GRADES PER PROBLEM							
Percent Average	81%	63%	74%	84%	63%	84%	78%	75%
Standard deviation	15%	30%	18%	19%	26%	18%	24%	16%
SECTION 3 FINAL	SECTION 3 GRADES PER PROBLEM							
Percent Average	85%	65%	70%	80%	72%	86%	78%	76%
Standard deviation	13%	27%	21%	17%	17%	14%	24%	13%

Overall grades were high, and variations in grade across sections tracked with average section GPA. Though final exams are not returned to the students at Florida Tech and past examples of the final were not provided, the exam was cumulative, and for the first time the class all students had nine examples of in-class exams to study from (one from each instructor for Exams 1, 2, and 3). Student comments indicated working past exams was a good way to prepare for future exams, and this may help to explain the high grades on the final.

Conclusions

The experiment of developing a common framework at the Florida Institute of Technology was overall a positive experience. From a student perspective, common homework and a common final exam reduced one set of reasons for students to comparison shop for different sections and instructors, and using the online homework system reduced another source of variability caused by different graders.

It should be noted that most students still prefer a conventional class lecture format with active learning over the hybrid flipped approach. Flipped teaching puts explicit expectations on students to take charge of their own learning, and students are often not willing to put in the required course preparation to make the in-class group problem solving most productive.

From an instructor perspective the commonality exercise was successful. Having colleagues to share ideas and concerns with was very helpful, especially for newer instructors. Visual aids and best practices were shared, and instructors occasionally attended each other's classes. The three-person instructor team took a "divide and conquer" approach to things like setting up the online homework, developing grading rubrics and selecting problems. Grading the common final also worked smoothly. Because instructors were grading a fewer number of different problems, there were fewer decisions to make about the amount of partial credit to be awarded for imperfect work, which streamlined the process. Though only a small amount of the data obtained in the end-of-course survey was reported in this paper, the student responses provided a wealth of information that will be used by the instructors as they continue to improve the quality and consistency of statics instruction at Florida Tech.

The "Hawthorne Effect" (or "observer effect") is a psychological term for the tendency for subjects in research experiments to perform better and increase productivity because they are being observed [15]. Because the instructors are in effect observing each other and comparing outcomes, there is both intrinsic and extrinsic motivation to do well. Some self-improvement models are based on an action-observation-reflection cycle [16], but if instructors are teaching alone without external input, it may be difficult for them to be objective about their outcomes and take time to reflect how things might be better. Based on our experience with the Statics program at the Florida Institute of Technology, we believe that when we work together to share best practices and compare data on outcomes, everyone wins.

References

[1] H. J. Walberg, R. A. Paschal and T. Weinstein, "Homework's powerful effects on learning," *Educational Leadership,* vol. 42, no. 7, pp. 76-79, 1985.

[2] H. Cooper, J. C. Robinson and E. A. Patall, "Does homework improve academic achievement? A synthesis of research, 1987–2003," *Review of Educational Research.,* vol. 76, pp. 1-62, 2006.

[3] R. Hibbeler, Engineering Mechanics: Statics (14th edition), Pearson Prentice Hall, 2016.

[4] Pearson, "Pearson Mastering Engineering and Computer Science," Pearson Education Inc, 2018. [Online]. Available: https://www.pearsonmylabandmastering.com/northamerica/masteringengineering/. [Accessed 20 January 2018].

[5] A. Fernandez, C. Saviz and J. Burmeister, "Homework as an Outcome Assessment: Relationships between Homework and Test Performance," in *Annual Conference of the American Society of Engineering Education (Paper ID#2006-67)*, Chicago, IL, 2006.

[6] R. O'Neill, A. Badir, L. D. Nguyen and D. J. Lura, "Homework Methods in Engineering Mechanics, Part 2," in *Annual Conference of the American Society of Engineering Education (Paper ID#16553)*, New Orleans, LA, 2016.

[7] D. J. Carpenter, T. Harding, C. J. Finelli, S. Montgomery and H. Passow, "Engineering Students' Perceptions of and Attitudes Towards Cheating," *Journal of Engineering Education,* pp. 181-194, 2006.

[8] Pearson Education Inc, "Mastering Engineering Educator study investigates homework copying at Texas Tech," 2017. [Online]. Available: https://www.pearsoned.com/results/mastering-engineering-educator-study-investigates-homework-copying-texas-tech-2/. [Accessed 30 Jan 2018].

[9] A. Williams, "Online homework vs. traditional homework: Statistics anxiety and self-efficacy in an educational statistics course.," *Technology Innovations in Statistics Education,* vol. 6, no. 1, 2012.

[10] V. Berandi, "The impact of using randomized homework values on student learning. The Journal of Effective Teaching. 2011; 11(2): 4-7.," *The Journal of Effective Teaching,* vol. 11, no. 2, pp. 4-7, 2011.

[11] S. Condoor and S. Jayaram, "Learning Statics- A Foundational Approach," in *Annual Conference of the American Society of Engineering Education AC 2008-2105*, 2008.

[12] T. Ji and A. J. Bell, "Seeing and touching structural concepts in class teaching," in *The Proceedings of the Conference on Civil Engineering Education in the 21st Century*, Southampton, UK, 2000.

[13] D. W. Johnson, R. Johnson and F. Smith, Active Learning: Cooperation In The College Classroom., Edina, MN: Interaction Book Company, 2006.

[14] M. Jensen, A. Howard and S. Jensen, "Flipped Classes: Do Instructors Need To Reinvent the Wheel When It Comes To Course Content?," in *Annual Confererence of the American Society of Engineering Education, Paper ID #12519*, New Orleans, LA, 2015.

[15] J. McCambridge, J. Wilton and D. Elbourne, "Systematic Review of the Hawthorne Effect: new concepts are needed to survey research participation effects," *Journal of Clinical Epidemeology,* vol. 87, no. 3, pp. 267-277, 2014.

[16] A. E. Colton and G. A. Sparks-Langer, "A Conceptual Framework to Guide the Development of Teacher Reflection and Decision Making," *Journal of Teacher Education ,* vol. 44, no. 1, pp. 45 - 54, 1993.