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Can It Work for Us Too? Results from Using West Point's Fundamentals of Engineering Mechanics and Design Course Redesign.

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Can it work for us too? Results from using West Point's Fundamentals of Engineering Mechanics and Design course redesign.

Abstract

At the 2017 ASEE National Conference and Exhibition two papers from the US Military Academy (one in the Mechanics Division and one in the Civil Engineering Division) detailed a redesign of their initial mechanics sequence and the introduction of Inquiry Based Learning Activities. The authors of those papers extended an offer to share details and materials of their course redesign and associated lesson activities. The authors of this paper took them up on that offer and in the Fall of 2017 implemented the changes proposed at the US Military Academy at York College of Pennsylvania. The question this paper strives to answer is, can a similar course redesign produce similar results at an institution, that in many respects is very different from the US Military Academy; essentially is the West Point redesign reproducible and the results replicable and if so under what conditions?

This paper will strive to use many of the same measures from the original paper in the analysis of the success or failure of the implementation. The paper will also examine and document the differences between the students and institutions. It will then note differences in the administration of the course, changes made, and conduct of the course, to include number of instructors, sections, section size, group size and the demographic make-up of students in the course and list the effect of the differences discovered at this time. Finally, considering differences and similarities, the paper will analyze and capture the results and the effects of the two applications of the course redesign to come up with an answer to the research question.

Introduction

At the 2017 ASEE National Conference and Exhibition two papers from the US Military Academy (one in the Mechanics Division and one in the Civil Engineering Division) detailed a redesign of their first two courses of their engineering mechanics sequence, covering the material typically found in both statics and mechanics (or strength) of materials courses as well as the introduction of Inquiry Based Learning Activities [1, 2]. The papers detail the process engaged in during and the reasoning behind the redesign and development of activities for what was, through all previous assessments, a popular and well received course sequence. As a result of their internal assessment the faculty from the Department of Civil & Mechanical Engineering at the US Military Academy [USMA] at West Point determined that their first sequence of engineering mechanics courses provided the technical content that was required, but the courses were lacking in a few areas and would benefit from some updating. Among the updates, they desired to teach their first course (which combines statics and introductory mechanics topics) as part of the broader design process. Further, they wanted to integrate the use of computer programs to begin the education of their students on the effective use of programs (and understanding their limitations). Finally, they hoped to provide the inspirational time, space, and

structure necessary for students to apply their knowledge in a way that demonstrated a broader understanding of course principles through creating or discovering their own solutions (rather than simply performing calculations demonstrated in class).

During their presentation the authors of those papers extended an offer to share details and materials of their course redesign and associated lesson activities with other programs. At York College of Pennsylvania [YCP], statics was taught in a very traditional fashion as a follow-on course to physics, and was largely done through fairly straight forward demonstration of writing solutions for typical textbook problems. As a new faculty member in 2016, the author relied on a more active learning style in the course with demonstrations, real world problem sets and an emphasis on students solving problems. Seeing the presentation at the ASEE conference in 2017, this course redesign seemed to offer the next step in improving the course and student learning.

With the addition of another new faculty member in 2017, the decision was made to implement the changes proposed by the USMA faculty at the 2017 ASEE conference, with assistance from West Point. The question this paper strives to answer is: can a similar course redesign produce similar results at another institution, that in many respects is very different from the US Military Academy? Essentially, is the West Point redesign reproducible and the results replicable and if so, under what conditions? It is also an aim of this paper to present the challenges, issues, and successes of implementing this plan with the objective of aiding other programs who might want to incorporate the ideas originally detailed by faculty from the US Military Academy in their engineering mechanics sequence redesign.

The motivation, reasoning and objectives of this redesign were presented in the first paper [1]. These all were agreed with by our faculty and we could see no pedagogical reason for not using this innovative approach to attempt to achieve the same positive results. The faculty at West Point was most helpful and provided files with a study guide, including lesson objectives, comments on each of the lessons, detailed instructor notes for each lesson, copies of problem set assignments, sample exams, and supply lists for purchases to support the Inquiry Based Learning Activities (IBLAs) [2] they had laid out for their course. The West Point faculty was also very supportive with answering email inquiries throughout the semester with periodic questions about equipment used or specifications for models to be created.

Institutional Comparison

Our two institutions are similar in a few ways and very different in others. For example, York College is, like the US Military Academy at West Point, focused on undergraduate education with an emphasis on teaching and our two institutions are roughly the same size. West Point has a basic classification as Baccalaureate Colleges: Arts & Sciences Focus and our college is Master's Colleges & Universities: Small Programs with the undergraduate being professions plus arts & sciences, some graduate coexistence, on the Carnegie Classification of Institutions of Higher Education [3]. Similarities, in almost every possible regard, end there, however. York College of Pennsylvania is a private college, they are public; YCP has only had engineering since 1995 (the mechanical engineering program was launched in 1995 and civil engineering in

2016), West Point is the nation’s first engineering school having taught engineering for over 200 years. Unlike West Point, York draws primarily from the local area, not a national pool. Differences in faculty size, student faculty ratio, as well as student body attributes (standardized test scores) are summarized in Table 1. At the start of the project one quest that arose was whether the implementation of this fast-paced redesign could achieve equally good results with a group of students who are not at a highly selective college and who, on paper at least, seem to have lesser capabilities (as measured by standardized college entrance test scores).

	West Point	York College
Total Number Student Body	4389	4288
Number Civil & Mechanical Engineering Majors/year	132	84
Students in course (Civil/Mechanical/Other)	49/83/119	16/55/1
SAT (V/M) ACT (E/M) Student Body	604/637 29/28	550/549 22/23
SAT (V/M) ACT (E/M) Civil & Mech Engr Students	624/679 30(C)	598/641 24/27
Student Faculty Ratio	8:1	15:1
FTE CE & ME Faculty	42	9 (6)*

*YCP teaches over 3 semesters, although faculty only teach 2 of them, so while having a total of 9 faculty only 6 were teaching during the semester for this course.

Table 1 Institutional Comparison of Faculty and Students

Course Differences

There were also significant differences in the course administration. At West Point course enrollments are limited to 18 per section school wide and for this course as well; we limited our sections to 25. At West Point there were 9 faculty teaching 15 sections of their course. While assigned faculty had other duties, only two of the nine at West Point were teaching sections of an additional course. In addition, West Point has a robust and highly skilled team of lab technicians to help with fabrication of physical models and set up of equipment, one was assigned to support these courses and did a good deal of equipment and IBLA set up. In comparison, at YCP, we had two faculty teaching 3 sections (two of 25 and one of 22 students), both faculty had other non-teaching obligations and one taught a section of a different course as well; there was no lab or technical support personnel. Clearly one unknown question at the start of this project was whether a much smaller, and more typically constrained, faculty with more limits on classroom space and less technical support could implement this ambitious redesign and manage the set ups, IBLAs, demonstrations and multiple models.

To the greatest extent possible we used the curriculum, lesson plans, similar problem sets and exams that were used at West Point. There were some subtle differences based on each school’s differing academic schedules. At West Point the course meet 2.5 times per week (Monday, Wednesday, Friday one week, then Tuesday, Thursday the next) for 40 lessons (32 55-minute lessons and eight 120-minute lessons, which included 2 mid-term exams) over 16 weeks. At York College the course met Monday, Wednesday, Friday for 41 attendances, each 90 minutes, over 14 weeks, and we also gave two mid-term exams. We followed the lesson content almost exactly as described by the West Point (the extra lesson was used as a EDP work session). A summary of these differences in the course is presented in Table 2.

	West Point	York College
Faculty teaching the course	9	2
Number of sections	15	3
Average section size	18	24
Class Meetings	32 @ 55 min, 8 at 120 min	41 @ 90 min
Meetings per week	2.5	3
Problem Sets	13	13
Lab Reports	1	0
Engineer Design projects	1	1
Mid-term Exams	2	2

Table 2 Comparison of Course Administration

One of the advantages West Point has, due to having a long established civil and mechanical engineering program with courses taught in multiple small sections, is a large collection of equipment and a plethora of physical models literally developed over decades that are geared to small group instruction. For example, West Point was able to have enough bench size tension testing machines to support groups of three or fewer performing two different IBLAs/Lab experiments. Being a much younger and smaller program, we do not have the classroom set up or lab space to support this amount of equipment nor do we currently have the actual equipment. As such, we did the ultimate tensile strength test lab as a student assisted demonstration in the lab, and we only ran seven of the eight IBLAs (we did not do the bolt shear IBLA), each done with larger groups of students (4-5 versus 3 or less). We were able to construct and use a few similar physical models, through efforts of a capable work study student with shop skills, but did not have a ready supply of models or lab technicians to call upon to fabricate many of them.

Assessment

At the end of the semester a course-wide survey was administered and 69 of the 72 students enrolled in the course completed the survey (10 bonus points, 0.5% of the course grade, were offered for completing the anonymous survey). The survey included three questions modeled off the questions asked at West Point. Two Likert scale questions measured level of agreement or disagreement with “The hands-on activities were effective for my learning in this course” and “Using SolidWorks in class and on assignments helped me better understand course concepts” (Figure 5). In addition, the following open-ended questions were used as well:

- Which hands-on learning activity was the most helpful for understanding course material?
- What was it about the hands-on learning activity that made it the most helpful?
- What was the best part about using SolidWorks this semester and why?
- What are some ways we could improve or enhance our use of SolidWorks to help your learning of course concepts?
- Any other comments on the use of Hands on Activities or SolidWorks in the course?

While not unanimous the clear majority of the students agreed that the hands-on activities were beneficial for their learning (see Figure 1 for results). It was interesting to see that a significant number of students listed the engineering design project (EDP), SolidWorks and other class demonstrations as the best hands on activities, even though we had not initially thought of them as hands-on activities. The EDP and SolidWorks were major components of the course redesign and some of the students clearly appreciated getting to work with them in this course. The EDP especially seems to have had a favorable impact on students' views of the course as they felt it had real world application and allowed them to do a "real engineering" project.

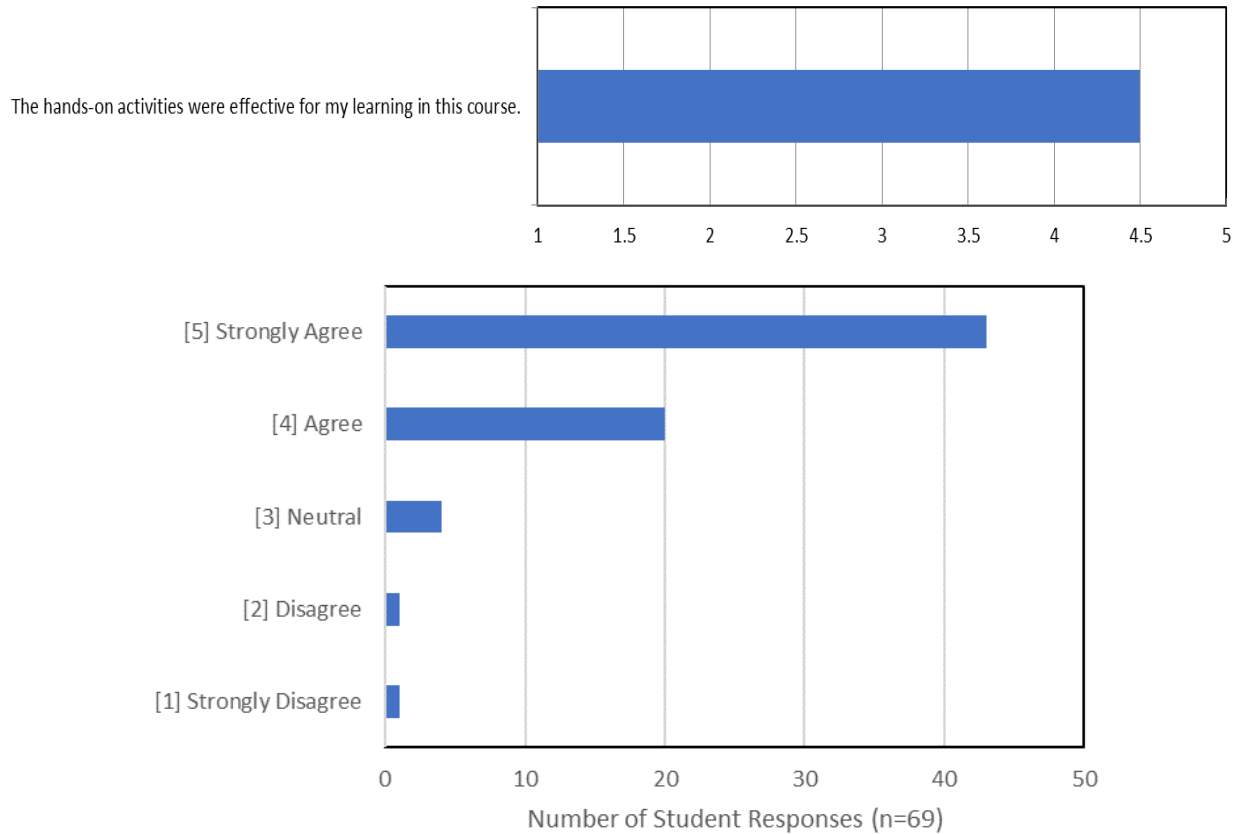


Figure 1 Student Feedback on Hands-On Learning Activities

A few representative student comments from the anonymous end-of-course survey explain what it was about the hand-on activities that made them valuable to students. From these comments and several similar ones it shows clearly what the research has told us for years, students want to see a real world (physical) connection to what they are doing in the classroom and what they expect to be doing once they graduate [4, 5]. Sample student responses that reflect this included the following from the course survey:

- I think the part that made the activities most beneficial was the fact that they reinforced many of the concepts that we had learned in class. They also helped us realize that the math we were doing in class had a real purpose and also was able to be closely replicated in the real world.

- It applied what we were learning on paper and helped us to visualize what was actually happening. I feel as though many engineering students are visual learners.
- The concept was a little confusing on paper to me so doing a real life 3D application made it make a lot more sense.
- The activities made the course much more bearable, and enjoyable... they were a good example of physical applications of statics that we can actually see. They were great.
- It gave us a visual representation of everything we are learning. It also shows a physical model on how something we made can actually function.
- It is just a relief to see principles learned in class applied to real life. Seeing the actual world work the same as it should on paper is a huge motivation booster. No one wants to learn about stuff that does not affect their life. I like doing all the hands-on learning because it proves that the material we are learning and the classes I am paying for are all relevant and needed.

Similar to the findings at West Point, our course end survey indicated that students appreciated being able to see theoretical concepts applied in a physical manner. Our word cloud from the open-ended comments about the hands-on learning activities (Figure 3) is very similar to the one they created from student comments as well. Students also indicated that they enjoyed being able to do things with their own hands. While, over 80% of the students met all the course objectives and only five students (7% of the course) failed to get a 70% course average, this is in line with the previous year's course offering. As with the West Point study the long-term benefits of this new course, and the new objectives, are unknown at this time and will not be seen for a couple of years.

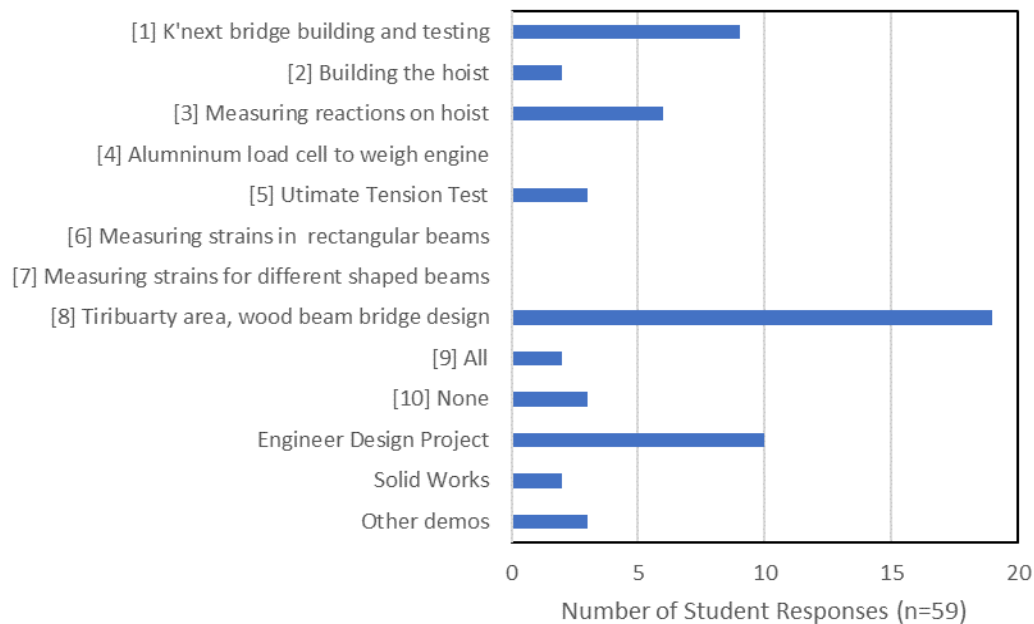


Figure 2 Student Feedback on Which Hands-On Learning Activity was Best*

*EDP and SolidsWorks are not truly Hands-On Learning Activities, but were mentioned by students in answer the question about the best hands-on activities

- Helped me learn to use SolidWorks simulations and how we can use it to help us with many statics calculations
- It was always a good feeling when our solidworks finally matched our hand calculations.
- Being able to see the stress diagrams because it shows visually what would happen and we can compare to hand calcs

The fact that several students were using SolidWorks to check their solutions and were using their hand calculations to verify their SolidWorks models was viewed as an added benefit and a significant learning experience. The word cloud from SolidWorks shows the prevalence of this (Figure 5).

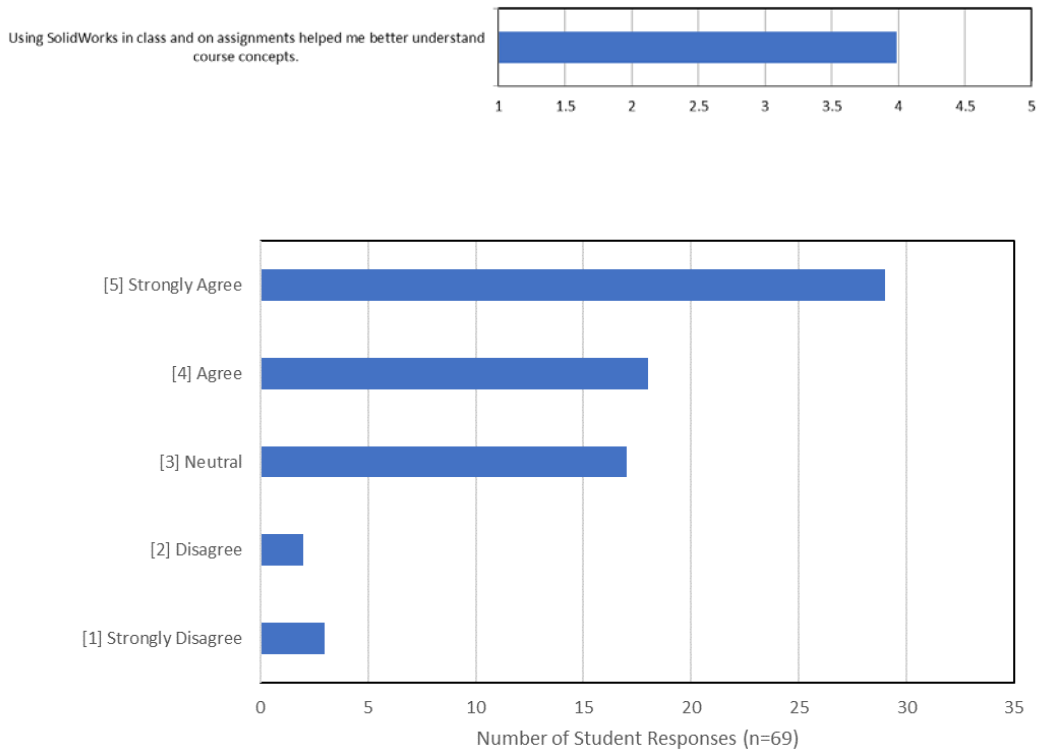


Figure 4 Student Feedback on Usefulness of SolidWorks

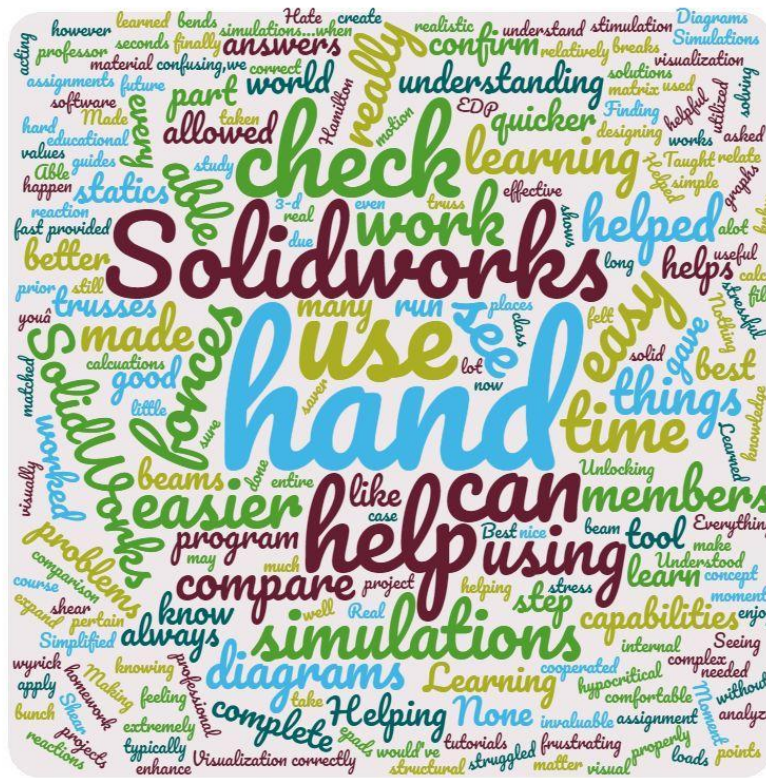


Figure 5 Word Cloud of Students Comments Regarding Use of SolidWorks

As a final open-ended question, students could also share other comments about the use of hands-on activities and SolidWorks in the course. A few sample comments clearly demonstrate the value that students saw in the measures undertaken in the course redesign:

- I really like how many hands on activities we do and the variety. It keeps class interesting and relevant.
- Adding SolidWorks was a good idea. Hands on Activities should be continued as well.
- I think hands on activities and solidworks is what this course should be built upon. You guys did a good job this semester but I would increase the hands on activities and time spent on solidworks in class.

From the student assessments it was clear that the students liked the course and definitely saw the value of the addition of SolidWorks, the IBLAs and the EDP. The authors feel in regard to the question this paper set out to originally answer: yes, a similar course redesign can produce similar results at another institution, even one very different from the US Military Academy; and the results are replicable. The final sections of this paper will address some of the practical experiences we encountered that others could benefit from if their institution were to implement a similar course redesign.

Challenges

The authors believe that it is worth briefly describing some of the challenges that were faced with our implementation. We do this so that others can better realize what is required to implement such changes. We also recognize that each institution has its own structure, systems, support, challenges, strengths, and characteristics; it is hoped that by detailing our experiences others will be able to apply the appropriate findings to their situation if they desire to replicate this model at their institution.

Despite receiving a very complete course layout, descriptions, instructions, and equipment list, implementing this course plan was challenging for a relatively new program, mostly due to the lack of robust resources including personnel, time, and equipment. While not insurmountable, the lack of resources meant our implementation was neither simple nor easy. Not having the equipment and models that West Point had meant we had to produce or procure many of them. With a lack of administrative support for ordering equipment and materials that West Point enjoys, this task fell solely on the instructors: yet another task that was not difficult, but still a significant and time-consuming activity. A lack of equipment did require us to skip one IBLA and modify the student participation in two others. Some of the physical setups for IBLAs and demonstrations that the West Point technicians fabricated in house, we had to send out for fabrication. This likely cost us more but was a very feasible alternative. Table 3 provides the approximate amount spent on each IBLA/Demo. As a new program we did not have much equipment available. While over \$13k seems like a large cost for one course, much of what we bought was a one-time cost and can also be used in other classes or support other activities, i.e. spring scales, K'nex, calipers, adjustable wrenches, strain gage reader boxes, etc.

It should be noted that with larger groups and larger classes many of these activities took more time to accomplish. This could be mitigated with additional equipment to set up extra testing stations, and more area for students to work. Space was an important limitation. While at West Point the classrooms are largely dedicated to a single course, we had to share space with a different course coming in between sections of our course. This at times made the setup more difficult to accomplish in a limited amount scheduled between classes. Our classrooms are also fairly full of chairs with attached writing desks, which although are moveable fill the room so we did not have the space to bring in an engine hoist or to be able to set up a 4'x 8' bridge. We were able to use a nearby project workspace, but moving to and from it during class, setting it up, coordinating for the space required additional time both in and out of class. It ought to be noted that although many students appreciated the inclusion of the engineering design project and SolidWorks, and there is evidence they recognize the benefit of their inclusion to the course, both of those required substantial amounts of instructor time and effort.

Another challenge we encountered having only two faculty members teaching the course, vice 9 or a larger number, was the time required for each of us in developing common exams, problems sets, EDP options, solutions, and course materials. Being able to divide up this work would have greatly helped, especially considering the time required to rehearse and set up IBLAs and demonstrations. Having sections that were 33% larger also increased the amount of time needed for grading.

IBLA/Demo/Equipment & Supplies	Approximate Cost
1. K'nex Bridge building/testing (spring scales, buckets, K'nex)	\$850.00
2. Engine Hoist measuring reactions (scales, hoist, engine block, wrenches)	\$950.00
3. PASCO Pulley (6 sets)	\$1,650.00
4. Aluminum load cell to weigh engine ¹	\$2,200.00
5. Measuring strains in rectangular beams (4 sets) ¹	\$5,975.00
6. Measuring strains for different shaped beams (aluminum stock, fabrication of supports)	\$650.00
7. Tributary area wood beam design (lumber)	\$325.00
8. Various other demos (bungee cords, spring scales, tape measures)	\$550.00
Total	\$13,150.00

¹ Includes purchase of strain gage reader boxes (1 for #4 and 3 additional for #5)

Table 3 Approximate Cost for Hands-on Activities

Going forward

With experience of a first iteration under our belts, we plan to continue to implement all the original West Point design changes into the course. As a new program (civil engineering), we will be purchasing new equipment which will allow us to incorporate the IBLA for bolt shear. Purchasing more equipment will also allow us to involve more students directly and increase interaction, especially with the beam bending exercises. Our program will soon be moving to a new building dedicated to civil engineering, which will better accommodate this style of instruction and is expected to alleviate some of the space limitations we experienced. The bigger question, unable to be answered at this point, will the effects of these changes be seen as positive benefits for the students later on in their course work and studies and can they be measured and attributed to this course redesign. This is a subject for future assessment and study.

Summary

The implementation was certainly an overall success. Course evaluations exceed both the department and institution averages and student comments were favorable. Anecdotally many of the students who took the course in the previous year kept looking in or asking us “why didn’t we get to do that?” While this is all very positive and definitely shows the West Point redesign can be replicated, it must be noted that certain conditions made this possible. Conducting a study such as they did, with senior faculty devoting time and effort to accomplish a thorough assessment of past work, a literature search and redesign of a course sequence and then implementation of such major changes in a relatively a short period would not have been possible at our college. Our much leaner faculty and less robust support system would not have made this possible. However, with the support from the Department of Civil & Mechanical Engineering at West Point we were able to do this. While not every large program might be as generous with their effort as theirs was, for those that are they can significantly impact students beyond their walls and move the engineering education community forward, benefiting not only

their students but engineering students in other institutions. This type of partnership is a viable way for smaller programs, who are often resource constrained, to be able to offer to their students an outstanding educational experience similar to those who attend more prestigious, and in this case, some of the top-rated programs in the country. These types of partnerships will certainly help our profession at large.

References

- [1] J. C. Bruhl, J. L. Klosky, & J. P. Hanus, "Let's Break Stuff! A Refit of the Mechanics Sequence of Courses to Inspire Student Inquiry," in *2017 ASEE Annual Conference & Exposition*, Columbus, Ohio, 2017.
- [2] J. C. Bruhl, J. L. Klosky, T. Mainwaring, and J. P. Hanus, "Accelerating the Development of Engineering Judgment in Students through Inquiry-Based Learning Activities," presented at the 2017 ASEE Annual Conference & Exposition, Columbus, Ohio, 2017.
- [3] Indiana University Center for Postsecondary Research. (2017). *Carnegie Classification of Institutions of Higher Education*. Available: <http://carnegieclassifications.iu.edu/>
- [4] R. W. Welch, S. J. Ressler, and A. C. Estes, "A Model for Instructional Design," *Journal of Professional Issues in Engineering Education and Practice*, vol. 131, July 2005 2005.
- [5] T. A. Angelo, "A teacher's dozen: Fourteen general research based principles for improving higher learning in our classrooms." *AAHE Bulletin*, vol. 45, pp. 3-13, 1993.