The Impact of Strength-Based Projects on the Engagement of Students in the Mechanics of Materials Course

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Topic: Work in progress

Abstract

The Mechanics of Materials course has been offered in flipped modality over the past 8 years at the University of Connecticut. This course is an entry-level course required for several engineering majors such as Civil, Mechanical, Biomedical, Materials Science, and Manufacturing Engineering. The goals of this flipped course are to improve student learning in large enrollment classes and promote inclusive teaching by providing online content to all the students. In this design, the lectures are delivered using pre-recorded videos. The in-person class time is used to present a brief recitation of the lecture material, discuss challenging concepts, and solve problems, individually or in groups.

A recent study evaluated the impact of using real-life examples by asking students to share images of engineering concepts. It found that while this activity benefits the learning of students, only a small group of students was motivated to actively participate. It was hypothesized that the single-domain approach relying on photography skills and interests of students is a limiting factor in broadening the participation of students. In the academic year of 2020-2021, a series of optional small strength-based projects (SBP) were added to the course to further improve student engagement and participation. Students were able to contribute to the course based on their personal interests and expertise. Students were prompted to identify one or more areas of interests such as photography, drawing, filming, sports, programming, computer gaming, comedy, woodwork, cooking, planting, poetry, reading, and puzzles. After students identified their area of interest, the instructor assigned individual, or group projects aligned with the student interests and course content. More than 25% of students participated in this activity compared to 5% in the previous single-mode approach. The participants created unique projects that are being used as learning materials in the course. This paper discusses the observations from this pilot implementation, the impact of strength-based projects on students' engagement, and the improvement in the students' learning experience. A retrospective survey was used to collect student feedback on whether this activity reinforced their sense of inclusion and improved their skills related to the implementation of their knowledge in real-life problems.

Modifications have been made on the structure of strength-based projects in the academic year of 2021-2022 to enhance students' experience and improve the quality of the projects. The changes and expected outcomes will be discussed in this paper.

Hypotheses and nature of data

This work is aimed to evaluate if using real-life examples and allowing students to contribute to the class materials by employing their strength, interest, and talents may enhance the students' engagement and improve their learning experience.

To investigate this hypothesis, the evaluation data from an anonymous survey completed by the participants and instructor's observations are presented and discussed. Because the evaluation activities used to inform this paper are limited to "systematic collection of information about the activities, characteristics, and outcomes of programs to make judgments about the program (or processes, products, systems, organizations, personnel, or policies), improve effectiveness, and/or inform decisions about future program development," [1] the author did not seek an IRB approval.

The Strength-Based Project (SBP) activity has been offered only in the classes taught by the author. This paper does not reflect data from course sections though by other faculty.

Background

The Mechanics of Materials course is a major requirement for many engineering disciplines including Civil, Mechanical, Biomedical, Material Science, Management and Manufacturing Engineering, and Engineering physics. The class has large enrollments of 100 to 120 students per section and an annual enrollment of 400 students. Considering the limited faculty resources and available space, the flipped version of the class was developed in 2013 to enhance the quality of the course, share uniformed resources to all students and provide alternative learning resources for diverse learners. In this flipped course, each lecture is presented with a pair of videos including a lecture video that presents the concept and formulations followed by a sample solving video where 2 or 3 problems are solved in step-by-step format. Each lecture is 50 minutes long and the class meets three times per week.

The class activity includes a short lecture by the instructor about the topics of the day followed by problem solving by students. The instructor and his/her teacher assistant guide students during problem solving activities and present the correct solutions on the board.

To enhance the students' engagement, pictures from real-life examples are shared during class short recitation. Students are asked to use the Think-Pair-Share method to discuss each picture. Figures 1 (a) and (b) display real-life examples selected to be discussed during class. Student Evaluation of Teaching results showed that more than 70% of students found real-life pictures helpful in their learning and said that "Real life examples showcased how theory applies in the world around us, making concepts more understandable" [2].

The Mechanics of Materials course was selected to be re-designed in the summer of 2020 as part of a research project funded by the Engineering Education Centers of the National Science Foundation to transform engineering education and create an inclusive learning environment that empowers neurodiverse learners [3]. While teachers value engagement as a critical component of working with students, the strength-based approach provides an easy roadmap that allows the student to promote the things that they are good at [4].

(a) (b)

Figure 1. Real life examples of engineering concepts, a) Double shear connection in Student Union, Storrs Campus, b) Overturning due to eccentric axial loading [5]

To offer a multi-domain approach relying on the variety of skills and interests of the students and to provide an inclusive environment, a series of strength-based projects were added to the course in 2020-2021 to enable students to initiate, recognize, apply, and share real life application of mechanics concepts. To engage students furthermore with this activity, students were asked to employ their interest, talent, or strengths towards their projects. This paper will discuss the implementation method, instructor's observations, and students' feedback from the pilot of this activity from 2020-2021. The applied changes in SBP projects in the 2021-2022 academic year will be presented.

SBP components and policies

Strength based projects were added to the course components as an optional activity allowing students to earn extra points towards their midterm exams. This extra point was equivalent 0.75-1.5 points towards their final grade per each submitted project. Because of large class enrollment and limited resources, the strength-based project was not defined as a mandatory class activity. Students were able to submit strength-based projects relevant to the topics covered every 4-5 weeks (approximately 3 chapters of the textbook). Therefore, they could submit up to 3 projects for 14 weeks long semester.

Students were prompted to identify one or more areas of interest such as photography, drawing, filming, sports, programming, computer gaming, comedy, woodwork, cooking, planting, poetry, reading, and puzzles. Google Forms were used to collect students' information including their names, major, interests, and their potential project. Examples of potential projects relevant to different strengths were provided to students as shown in Table 1. Later, students were contacted by the instructor via a personal email to discuss and finalize the topic of the SBP project. In addition, a follow up email was sent to students at the mid-interval of each mini project (2 weeks after signup and 2 weeks before deadline) to monitor their progress.

Students had approximately one month to complete each project for each module. Students were given variable choices to present their projects including a PowerPoint presentation, short video, written report, poster, or model (for the crafting fields). An online exhibition was created in the course blackboard section (HuskyCT) to share the students' projects with the class. This

exhibition benefitted other classmates to find applications of mechanics concepts in different areas.

Table 1: Suggested areas for the strength-Based projects

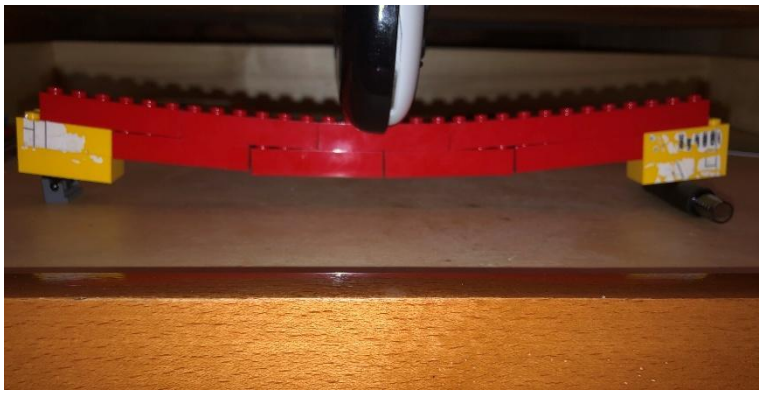
Strengths/Talents/Interests
● **Drawing:** Contribute to sketching the summary of each chapter and presenting mechanic's concepts. ● **Photography:** Take professional photos of real-life applications of Mechanic's topics. ● **Film making/Animation:** Collect movies to show failure due to poor structural design with explanations/Funny videos (like AFV) that can justify the event with mechanic's concepts. ● **Computer programming:** Write a program that can ease your calculations or do parametric studies for different concepts. ● **Web design:** Present projects on the class website and share with the community of engineers. ● **Game design:** Design a game based on the concepts you are learning in this course. ● **Crafts:** Making things out of materials. Help the instructor with building sophisticated demos for the class. ● **Sports**: Analyze sports gear for the applied stresses. Analyze the body of an athlete while playing a sport. ● **Fishing:** Analyze fishing tools under different loading. ● **Planting:** Analyze the structure of plants under wind, rain, and snow. ● **Caring for animals:** Explain why animals have different structures in their body. Explain how stress and strain look like in their body. Analyze or design pet accessories under different loading. ● **Woodworking:** Help the instructor with building sophisticated demos for the class. ● **Music:** Design or analyze instruments (or their parts) under different loading. ● **Cooking/baking:** Analyze or design cooking gadgets. ● **Mechanical tinkering (Robotics, cars, fixing mechanical items, etc.):** Analyze car or machinery elements. ● **Fashion:** Analyze fashion accessories under loading. ● **Reading:** Share historical structure failures or catastrophic events (relevant to Mechanics of Materials topics) from articles or books you have read. ● **Puzzle solving (crossword puzzling):** Design a crossword for a Mechanics of Materials concept. ● **Astronomy:** Design or analyze a telescope or parts of a spaceship. ● **Graphic design:** Help with sketching concepts/summarizing topics in a nice format. ● **Lego Building:** Analyze Lego brick structures, design stable Lego structures under loading. ● **Yoga:** Analyze the body and types of loading for different Yoga poses. ● **Standup Comedy:** Make a comic presentation of the class materials (appropriate enough for class audiences). ● **Pottery:** Analyze or design objects made of clay under different loading. Predict a failure area or improve a design.

Projects later were reviewed and graded by the instructor based on criteria such as clear and understandable presentation of the topic, accuracy, shown understanding of the topic, and creativity.

Sample projects

Students created unique projects. Samples of submitted projects are shown in Figure 2 from areas including woodworking, Lego building, poetry, and yoga.

(a)



(b)

To begin with this class
We have to go back to the basics
Review last years statics
Then proceed with mechanics

Free body diagrams
Will make you a problem solving hero
Label the angles and axes
The sum of the forces is zero

Indeterminate's no good
It means we don't have enough info
More unknowns than equations
It almost seems sinful

Moments have a force
That cause a rotation
Strain is delta/L
It means deformation

I don't mean feeling anxious
When I talk about stress
There's normal, bearing, and bending
Know P/A for the test!

(c)

(d)

Figure 2. Sample SBP projects, a) Demo of shearing stress in a built-up member, b) Lego beam under bending, c) Poem Explaining Mechanics Concepts, d) Yoga pose is modeled as a beam under loading

Other projects in areas such as standup comedy, game design, computer programming, photography, crossword puzzles, planting, and cooking were submitted by students. The instructor has made these projects available to students in other cohorts enabling them to see the application of mechanics concepts in different areas.

Observations

It was observed that students finished and submitted their SBP projects days before the deadline. Unlike other class assignments, there was no last minute or late submission for the SBP projects. This may be attributed to the fact that students found joy and satisfaction while completing the project as it was aligned with their interest. Students said:
"I enjoyed doing the projects because it was so free with what you could do. It wasn't like an assignment; it was a choice then you could choose what you wanted to do. It didn't feel forced."
"I love the SBPs I participated in. I never felt rushed to meet a deadline because I collected my

material throughout everyday life. I felt the projects made me observe my surroundings more often than I would. They also have made me realize just how technical structures can be".

Participants were told that their products would be used as course material. Therefore, they developed their projects with extra care to offer understandable and useful materials to their peers. A participant said: "The fact that my projects will be used in future courses for demonstration purposes makes me feel even more important because my name is attached to that creation. In a way, I guess it gives me a taste of what it feels like to design, create, and patent an engineering mechanism for future purposes, which is certainly not taught throughout the B.S. engineering pipe-line".

It was observed that some participants gained the self-confidence to express their ideas more often during class discussions. Such transitions in behavior can be explained by the impact of SBP on feelings of belonging and class engagement. As expressed by one of the students "I doubt my abilities a great deal and sometimes feel I don't belong in this field or am not capable of doing the work. Throughout the semester any small comment from you helped me feel more confident about my studies and pursuing a career in engineering. Specifically, when I was working on strength-based projects".

Conducting strengths-based projects demands time allocation, as it requires the faculty to work individually with each participant, provide feedback to each project, and meet with students. The large enrollment of the class and the limited teaching assistant resources are obstacles to integrating this activity in the course for all students.

It was observed in the second cohort of offering the SBP project (spring 2021) that more students with poor performance in the midterm exams signed up for the projects in the last module to earn extra points. A pattern of misconception was observed in the projects submitted by the students who had below average performance in the class. The instructor has added midpoint project feedback to SBP projects in the current offering to minimize errors. Further details are shared in the section of Future Work.

Students' feedback

An anonymous post-project survey conducted using Google Forms at the end of semester and responded by the participants whether participating in SBP has enhanced their feel of belonging, class engagement, understanding the concepts, class participation and skill of applying the concept in real life. The data is collected from two sections of the course in fall 2020 and one section in spring 2021. A Total of 71 students participated in SBP projects and 34 responded to the survey (47% response rate). The data is averaged and presented in Table 2.

Students were asked if they think similar strength-based projects are beneficial in other engineering courses. 88% of participants agreed or strongly agreed with this option. In addition, 71 percent of the participants expressed that Strength-Based projects should be an integrated course component and required for all students.

Table 2: Summary of student's response to the question if SBP enhanced

SBP Enhanced:	Agree/Strongly Agree (%)	Disagree/Strongly Disagree (%)	Neutral (%)
Feeling of Belonging	94	0	6
Class Engagement	100	0	0
Understanding of the concepts	94	6	0
Applying the concepts in real life	94	0	6
Class participation	76	6	18

Students expressed that participating in strengths-based projects enabled them to contribute something towards the classroom, as well as apply academic principles to real-life situations. Knowing that their projects will be used in future courses for demonstration purposes make them feel even more important and enhance their feeling of belonging within the engineering field. Students reflected in their feedback that they were more creative with their ideas because they could choose projects which were aligned with their interests. One of the students mentioned "I think the SBP projects made me think deeper about the concepts we learned in class and applying them to real life principles. It also made me more interested in the subjects because I could see where they came into play in my everyday life and the world around me."

Future work

To enhance the quality of the projects and offer a more structured grading system, projects were organized in two tracks of creative and analytical/design. Table 3 shows the topics listed under each track.

Table 3: SBP tracks in Fall 2021

Strength Based Project Tracks	
Creative	**Analytical/Design**
● Photography ● Film making/Animation ● Computer programming ● Game design ● Crafts ● Reading ● Woodworking ● Standup Comedy	● Sports gear ● Playground ● Toys ● Fishing ● Planting ● Caring for animals ● Musical instruments ● Cooking/baking gadgets ● Fashion ● Astronomy ● Lego Building ● Yoga ● Pottery

The crossword puzzles were removed from the list of topics as students were not able to demonstrate innovation or application of mechanics concepts truly in the previous cohort. Some students found this topic an easy way to earn extra points without spending actual effort.

Separate rubrics were designed for each track to provide a clear guidance to students about expectations and requirements. Tables 4 and 5 show the rubrics for creative and analytical tracks separately.

Table 4: Rubric for the SBP-Creative Track

	Proficient	**Developing**	**Beginning**
Organization	The project/product is neat or has fluency. (3)	The project/product is partially neat or has fluency. (2)	The project/product is not neat or does not have fluency. (1)
Mechanics concept relevancy	One (or more) of the course topics is employed clearly. (3)	It is hard to find which course topic is employed. (2)	It is not clear which course topic is used. (1)
Clarity	The content is clearly communicated. (3)	The content is partially communicated. (2)	The information is barely communicated. (1)
Creativity/Originality	The product is novel and innovative. (3)	The product is somehow novel and innovative. (2)	The product is not novel or innovative. (1)
Usefulness for other students	The product can be easily used by others. (3)	Using the product is complicated for others. (2)	It is not usable for other students. (1)

Table 5: Rubric for the SBP-Analytica/Design Track

	Proficient	**Developing**	**Beginning**
Organization and Visualization	The project/product is neat or has fluency. Pictures/graphs/annotations are used properly in the project (3)	The project/product is not quite neat or has fluency. Pictures/graphs/annotations are partially used in the project. (2)	The project/product is not neat or does not have fluency. Minimal Pictures/graphs/annotations are used. (1)
Mechanics concept relevancy	One (or more) of the relevant course topics is employed clearly. (3)	It is hard to find which relevant course topic is employed. (2)	It is not clear which relevant course topic is used. (1)
Data	Geometry, materials, dimensions, loading, and other assumptions are presented clearly. (3)	Geometry, materials, dimensions, loading and other are presented partially. (2)	Geometry, materials, dimensions, loading, and other assumptions are barely presented. (1)
Accuracy	Calculation of stress/Design are done correctly. (3)	There are numerical errors in calculation of stresses or design. (2)	There are conceptual errors in calculations. (1)
Usefulness for other students	The product can be easily used by others. (3)	Using the product is complicated for others. (2)	It is not usable for other students. (1)

In the fall 2021 cohort, students are required to submit a preliminary draft of their project using the assignment tool in Blackboard at the mid-interval of each mini project (2 weeks after signup and 2 weeks before deadline) to receive feedback from the instructor and implement suggested changes in their final submission.

An anonymous survey will be conducted at the end of the fall semester to collect the students' feedback and compare the results with collected data from previous cohorts. To determine the

effectiveness of changes made in the 2021-2022 cohort, the instructor will evaluate and compare the quality of projects submitted in the past three cohorts.

The Number of projects submitted in each track will be monitored and compared to find the preferred track among engineering students. The instructor will plan to expand resources for the areas that students show the most interest.

Conclusion

A series of optional small strength-based projects (SBP) were added to the course of Mechanics of Materials in the academic year of 2020-2021 to improve student engagement and participation. SBPs allow students to find and implement mechanics concepts in the areas of their strengths. Students were able to contribute to the course based on their personal interests and expertise.

More than 25% of students participated in this project and created unique projects. Other classmates benefited from SBPs by attending an online exhibition displaying submitted projects. More than 95% of participants agreed or strongly agreed that SBP projects enhanced a feel of belonging, class engagement, understanding of the concepts, and strengthened the skill of applying the concepts in real-life. The structure of SBPs have been modified in fall 2021 to improve the quality of projects and enhance the learning experiences. The students' feedback and quality of projects from the cohort of 2021 will be evaluated and compared with the previous cohorts.

References

[1] https://ovpr.uconn.edu/services/rics/irb/researcher-guide/does-evaluation-require-irb-review/#
[2] Motaref, S., "The Evaluation of Different Learning Tools in Flipped Mechanics of Materials", 2020 ASEE Annual Conference & Exposition Virtual Conference, June 20-24, 2020, Montreal, Quebec. https://peer.asee.org/35317.
[3] Chrysochoou, M. Syharat, C., Zaghi, A., Jang, S., Bagtzoglou, A., Motaref, S., "Redesigning Engineering Education for Neurodiversity: New Standards for Inclusive Courses", 2021 ASEE Annual Conference & Exposition Virtual Conference, June 27-30, 2021, Long Beach California.
[4] Brownlee, K., Rawana, E., MacArthur, J., "Implementation of a Strengths-Based Approach to Teaching in an Elementary School", Journal of Teaching and Learning, Vol. 8 No. 1, 2012.
[5] https://www.craneblogger.com/safety/self-erecting-crane-overturns-in-n-holland/2012/06/04/

Response to Reviewers:

Reviewer 1: Since the math is limited at this stage in their career as engineering students, does this make the job of flipping more difficult?

Response: Students take this course during the 2nd semester of their sophomore year or 1st semester of their junior year. They complete all required math courses during the freshman year Therefore, students have enough mathematical background for this flipped course.

Can you present the student feedback/course evaluations gleaned from this survey?

Response: The result of this survey is shared in Table 2.

What percent of class time is dedicated to this activity?

Response: Strength based projects are completed outside of class time. The length of project requires students to spend 3 to 4 hours on each mini project.

Is there a lab associated with this Mechanics of Materials course?

Response: No. The course has no required laboratory.

How many class hours are assigned to this course?

Response: The class meets 3 times per week for duration of 50 minutes (Total of 150 minutes per week). The paper was revised to address the reviewer's comment.

Having taught this course many times over the years, I would suggest the students, with their varied concentrations in engineering, research applications in their chosen major as well. Perhaps, this would be easier to manage, and the participation level would be higher.

Response: This is a great suggestion. The author will consider integrating this suggestion in the future offerings.

Reviewer 2:

Interesting and creative addition to this course. I loved reading the student feedback! I also appreciate the inclusion of rubrics for the different types of projects.

Response: Thanks a lot for your encouraging feedback!

Please review line breaks and spacing in the manuscript, as it is not consistent. Have another reader go through the manuscript and help with grammar and word choice.

Response: The spacing and breaks are fixed in the final version.

I am not sure why the Hypotheses and nature of data section is presented here. If you want to keep it, please make sure all terms are clearly defined (ex: readers don't know yet what the SBP activity is - be sure to define the acronym the first time it appears in the text and be consistent in only using the acronym in the following text)

Response: The SBP was spelled out for the clarification.

The Background does not need to go into detail between the switch from the 2016-2017 methods to the 2017-2021 methods (too much detail on a past curricular change was confusing). Simply focus on the latter in how it informs the current project design.

Response: The background was shortened per reviewer's suggestion.

It is not clear what was meant by "Students were able to submit UP TO 3 PROJECTS." Per exam or per semester? What was the total percentage that the 3 projects could add to their total class grade? Clarify at this point in the text with a follow-up sentence or two.

Response: The class is 14 weeks long. Students were able to submit Strength-based projects relevant to the topics covered every 4-5 weeks (approximately 3 chapters of the text book). Therefore they could submit up to 3 projects during the semester. Extra point was equivalent 0.75-1.5 points towards their final grade per each submitted project. The paper was revised to address the reviewer's comments.

Were additional points given to students to encourage to visit the exhibition space on the course blackboard in order to review their peers' work? Or was there some other formal way to make sure they did? If so, please describe. If not, I recommend trying it.

Response: No, Visiting the virtual exhibition was optional. I could enable statistics tracking to check if students click on the projects in Blackboard. I will consider your suggestion and will add a policy to encourage other students to visit these projects. Thanks for your great recommendation.