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Active Learning Experience Incorporating Entrepreneurial Mindset in Engineering Mechanics Course

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Introduction

An increasing number of engineering professors have been using active learning experiences to engage students. Moreover, active learning techniques have been shown to increase student performance in several settings [1], [2], [3], [4] and may help close achievement gaps for underrepresented students in STEM majors [5]. Active learning experiences are broadly defined as activities that students do to further knowledge and understanding of a topic and can be anything from brief pauses during lectures to allow for reflection to semester-long off-site projects. Active learning can be particularly beneficial for the most challenging aspects of a course, such as the analysis of frames and machines in a statics and dynamics course for which students must apply their knowledge of several previous topics to systems with complex structures and multi-force member(s).

Additionally, entrepreneurial mindset learning (EML) has been incorporated into engineering programs. Through EML, student learn how engineering principles combined curiosity and a desire to solve problems can be used to create value for others. Groups like KEEN have been supporting and encouraging EML in engineering education, with the publication of the "The KEEN Framework" that includes examples of student outcomes associated with entrepreneurial mindset [6]. Most often, these EML outcomes are incorporated into first year and capstone courses that emphasize the engineering design process. Courses, such as statics, dynamics, and thermodynamics, make less frequent use of EML, possibly because instructors feel like they do not have enough class time to include these elements. The aim of the "Clippers Worth the Cost" activity is to incorporate EML with course content in such a way that students' experience with the content is more meaningful and increases their confidence in their ability to achieve the course's learning outcomes.

Project Approach

This EM activity took place in a semester long engineering mechanics course, Statics and Dynamics. At this university, statics and dynamics is a four-credit hour course required for students majoring in biomedical, civil, and mechanical engineering. The course meets for lecture three times per week for 65 minutes and is supported by a laboratory that meets for one hour and forty minutes once per week. Statics and Dynamics students worked in groups of 3-4 to complete this activity.

For the activity, students were given the "Clippers Worth the Cost?" handout and dimensioned pictures of the standard and "Power Lever" garden clippers. These handouts are included in the appendix. The "Power Lever" clippers were also available for the students to experiment with.

Briefly, the instructions were to analyze the forces in the members of clippers to determine if the advertising claim that the "Power Lever" clippers cut two times more easily than the standard was true, identify at least three stakeholders that have an interest in these clippers, find additional products that might preform the same function as the clippers, list as many features of these products that the stakeholders might value as possible. Next, groups used

markers and easel sized post-it notes to create concept maps depicting the value of the clippers. In their concept maps, students connected the stakeholders to the features with lines that describe how the feature creates value for the stakeholder, such as expects, delights, and detracts and connected the products to the features with lines indicating if that product was better worse or the same as the standard clippers. Finally, students presented their work with a gallery walk and made a judgement if the clippers with the "Power Lever", which cost about $10 more than the standard clippers, were worth the additional cost.

Results and Discussion

Sophomore level engineering students completed the "Clippers Worth the Cost" activity during the statics portion of their engineering mechanics course, Statics and Dynamics. Prior to the activity, students watched an asynchronous instructional video on how to perform equilibrium analysis of frames and machines and completed textbook problems on this topic. During the fall 2023 semester, when the activity took place, twenty-nine students, majoring in biomedical, civil, and mechanical engineering were registered for the course and twenty-three took part in the activity, which occurred during a 65-minute lecture period. The target EM student outcomes were adapted from The KEEN Framework: Form and work in teams, apply creative thinking to ambiguous problems, substantial claims with data and facts, and understand the motivations and perspectives of others [6].

At the beginning of the activity, students completed an anonymous survey rating their confidence level in three steps of the analysis process that they were taught: identifying members of a frame or machine, drawing free body diagrams of members of a frame or machine, and solving for forces in members of a frame or machine. The results of this survey are shown in

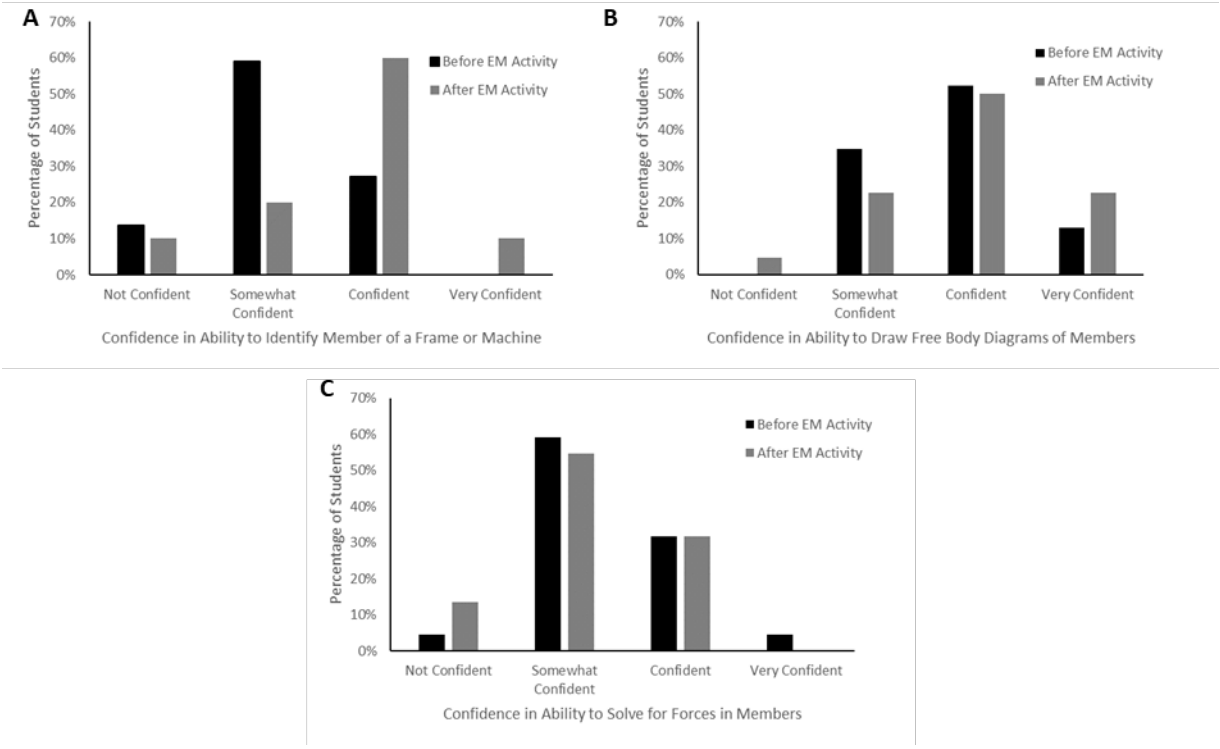

Figure 1: Survey Results Ranking Student Confidence in Their Ability to Identify Members of a Frame or Machine (Panel A; n=22), Ability to Draw Free Body Diagrams (Panel B; n=23), and Ability to Solve for Forces in Members (Panel C; n=22).

Figure 1 with the solid black bars. About 60% of the students indicated that they were somewhat confident in identifying the members of a frame or machine and an additional 27% said that they were confident in this step of the analysis. For the next step of the analysis, drawing free body diagrams of the members, 52% expressed confidence, 13% were very confident and 35% were somewhat confident. Most students rated their ability to solve for forces in members or a frame or machine as somewhat confident (59%) or confident (32%) or very confident (5%). Overall students reported feeling the most confident in drawing free body diagrams and the least confident in identifying members of a frame or machine.

Students completed the activity in two phases. The first phase focused on analyzing the forces in frames and machines and the second focused on entrepreneurial mindset and value creation. In first phase of the activity, students worked collaboatively with their group to evaluate the manufacturer's advertising claim that garden clippers with the "Power Lever" cut twice as easily as the standard clippers by comparing by comparing the mecanical advantage of standard garden clippers to that of the clippers with the "Power Lever". The procedure for making this comparison was intentionally vague to better represent problems practicing engineers face and to facilitate conceptual rather than algorithmic thinking, which is important for effective problem solving [7]. While calculating the mechanical advantage of each set of clippers, groups made decisions and assumptions to compensate for missing information, such as deciding to analyze the top or bottom handle of the clippers, assuming the location of the applied force, and determining the orientation of the clippers relative to the branch being cut. Based on which set of assumptions the group made, many different numerical answers could be correct. All of the groups correctly determined that the "Power Lever" clippers had an increased mechanical advantage when compared to the standard clippers. However, as expected, the numerical vaule calculated varied depending on the assumptions that the group made. None of the groups reported that the mechanical advantage was twice that of the standard clippers. Perhaps future iterations of the activity could challenge students to identify which assumptions would be necessary to show that the "Power Lever" clippers cut twice as easily as the standard version.

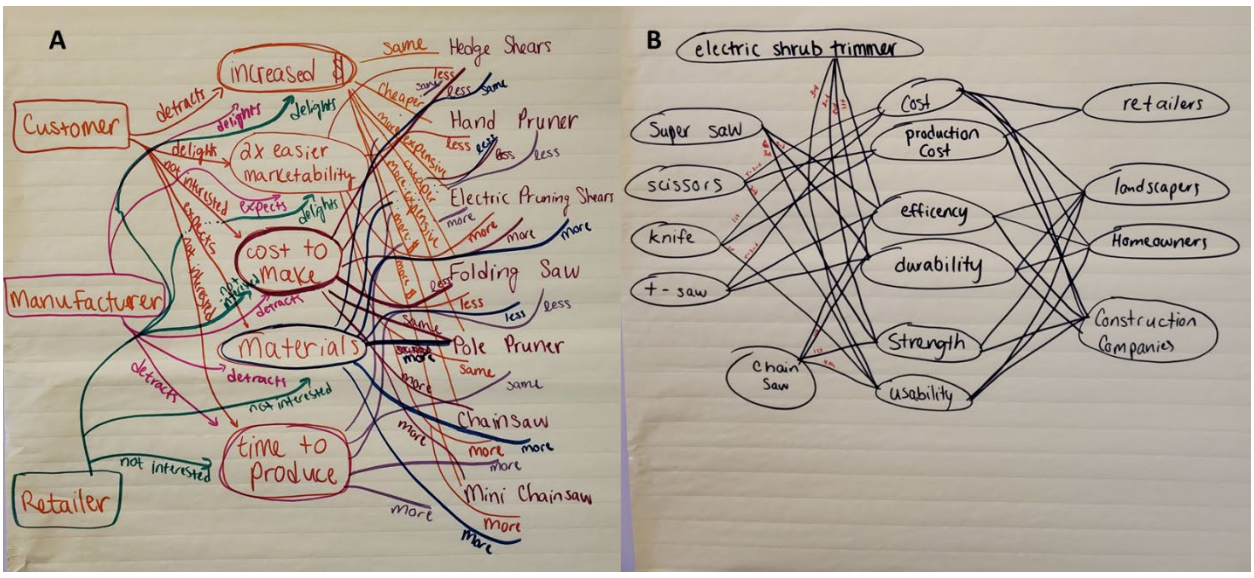

Figure 2: Examples of Value Creation Concept Maps made by student groups during the activity. A) Completed concept map B) Unfinished concept map

The second phase of the project delved deeper into entrepreneurial mindset. In this phase, groups created concept maps including features of the clippers, clippers stakeholders, and additional products that could also be used to cut branches. In their concept maps, students connected features of the clippers, such as ease of use, cost, and number of parts, to stakeholders, such as customers, retail partners, and manufacturer, with words that described how the feature created value for the stakeholders, like expects, delights, not interested in, or detracts. Students also had the opportunity to include on their concept map additional products that could be used for the same purpose and connect the products to the features with lines categorizing them as preforming the same as, better, or worse than the standard clippers. Concept map examples are shown in Figure 2. The connections helped students visualize how different stakeholders might value various features of the products. For example, the group that made the concept map in Panel A of Figure 2, indicated that the retailer might be delighted by the extra cost of the "Power Lever" clippers, but the customer viewed that feature as a detraction. Only two out of the nine groups completed their concept map by the end of the allotted time, possibly indicating that more time should be allocated to the activity. It is also possible that the groups stuggled with the mechanical advantage calculation and spent too much of the class period on this phase of the project. Overall, the value creation concept map helped students make a thorough judgement of which stakeholder(s) benefit the most from the different product designs and if the "Power Lever" clippers are worth additional the cost compared to the standard clippers. At the end of the activity, all the groups determined that "Power Lever" clippers were not worth the cost. This result was surprising because most groups calculated that the "Power Lever" clippers generated more force at the cutting surface and therefore would be easier to use. It is likely that students judged features other ease of use as contributing more heavily to the overall value of the product.

Finally, students repeated the survey rating their confidence level in three steps of the analysis process. Spending more time working collaboratively on a problem [8] and receiving postive feedback from peers and the instructor [9] during the galleray walk were expected to increase the students' confidence. The results of the post-activity survey are shown in Figure 1 as gray bars. After the activity, the ratings for confidence in identifying the members of a frame or machine increased the most, with the percentage of students feeling confident increasing from 27% to 60% and very confident from 0% to 10%. These gains likely result from those who were initially only somewhat confident, which decreased from 59% to 23%. Students also reported feeling more confident in drawing free body diagrams, but to a lesser extent. However, despite correclty determining that the "Power Lever" increased the mechanical advantage of the clippers, students felt less confident in solving for the members of a frame or machine. This loss of confidence was unexpected and might be explained by students feeling uncomfortable with the intentional ambiguity of the problem or being overconfident in their analysis skills at the beginning of the activity. Nonetheless, feeling more confident in the initial steps of the analysis process could be a meaningful positive outcome of the activity because it may give students the confidence to practice more of these types of problems.

Overall, this activity demonstrates how technical course content can be combined with entrepreneurial mindset. Working in groups to calculate the mechanical advantage of each set of clippers incorporated the technical content of a statics course and aligned with the EM outcomes of form and work in teams and apply creative thinking to ambiguous problems. The value creation concept map encouraged students to understand the motivations and perspectives of others. In future iterations of this activity, incorporating the mechanical advantage calculations

into the gallery walk presentation might work to increase the emphasis this aspect of the activity and encourage working in a timely manner, so that more groups could finish the concept map. Also, a partial example of the concept map might also help groups complete the entire activity within the allotted time. With additional time, groups could also be challenged to determine the assumptions that lead to the advertising claim, which would further strengthen the technical component of the activity. In conclusion, this activity is an example of how technical elements of a course can be combined with entrepreneurial mindset.

Acknowledgments

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Appendix

“Clippers Worth the Cost” Activity

Clippers Worth the Cost?

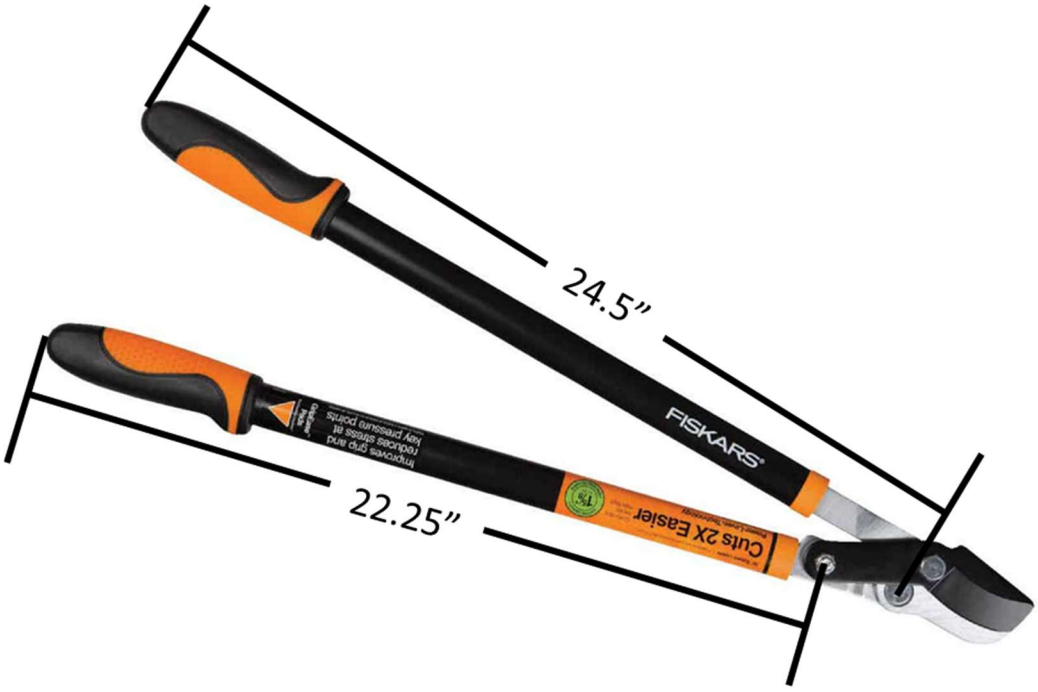
In this activity we'll:

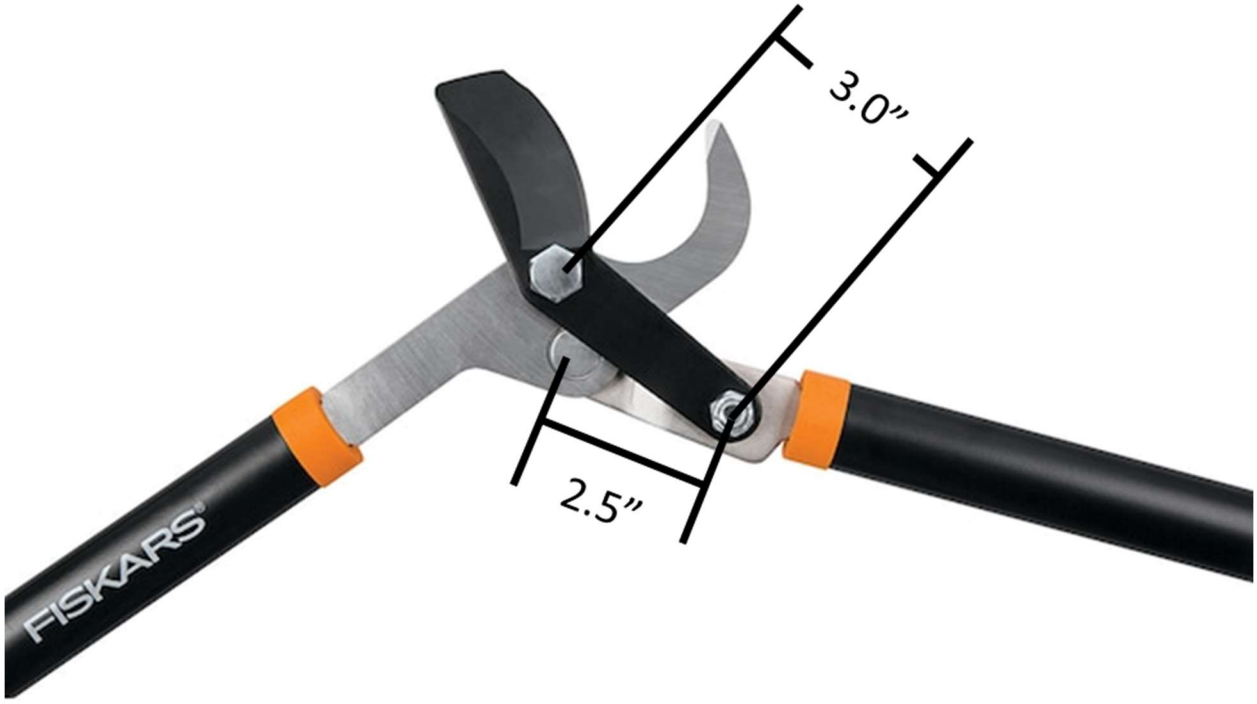
- Evaluate an advertising claim of a product.
- Identify stakeholders for the product.
- Relate how features of the product create value for the stakeholders.

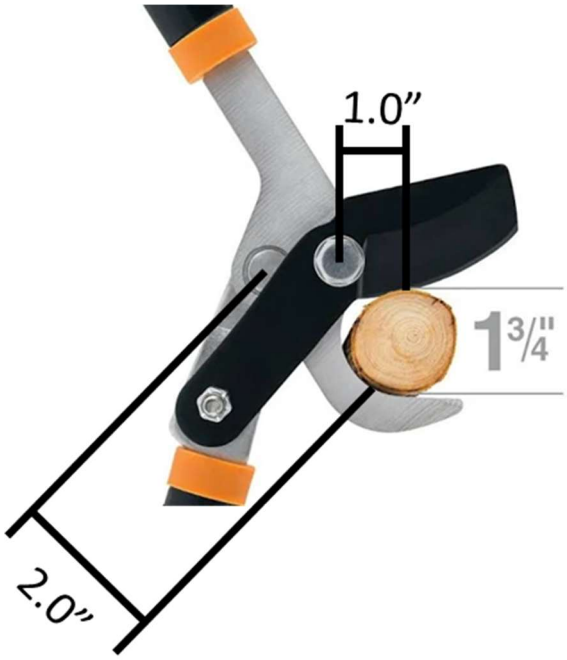
Fiskers makes two types of garden clippers or loppers used to prune medium-sized plant branches. The standard version has two long handles with blades at the ends connected by a pin. The other type has a "Power Lever" between the handles and the cutting blade. The "Power Lever" version claims that it "Cuts 2X Easier". Both types are available from retailers like Home Depot, Lowes, and Ace Hardware, often on display next to each other. The standard version has a retail list price of $20, while the "Power Lever" Version sells for $30.

1. Use your knowledge of how to analyze the forces in members of frames and machines and the dimensioned pictures to determine if the advertising claim that the "Power Lever" Version cuts two times easier is justified.
2. According to International Organization for Standardization standard number 26000 (ISO 26000), a stakeholder is an "individual or group that has an interest in any decision or activity of an organization". Identify at least three stakeholders that have an interest in these types of garden loppers.
3. Cutting ease and cost are two features of the product that stakeholder(s) might value. List as many features of the product that stakeholder(s) value as you can.
4. These products from Fiskars aren't the only ones that can be used to prune medium sized branches, for example Fiskars makes another type of lopper, with a "Power Gear". List other products that perform this function.
5. Make a concept map with the features you identified in the middle and the products on one side. Connect the products to the features with lines indicating if that product is better worse or the same as the standard loppers regarding that feature.
6. Add the stakeholders to the concept map on the other side of the features. Connect the stakeholders to the features with words that describe how the feature creates value for the stakeholder, such as expects, delights, not interested, and detracts.

Clippers with “Power Lever”






1.0”
1 3/4"
2.0”

Standard Clippers