Integration of the EOP Framework into First- and Second-Year Engineering Courses

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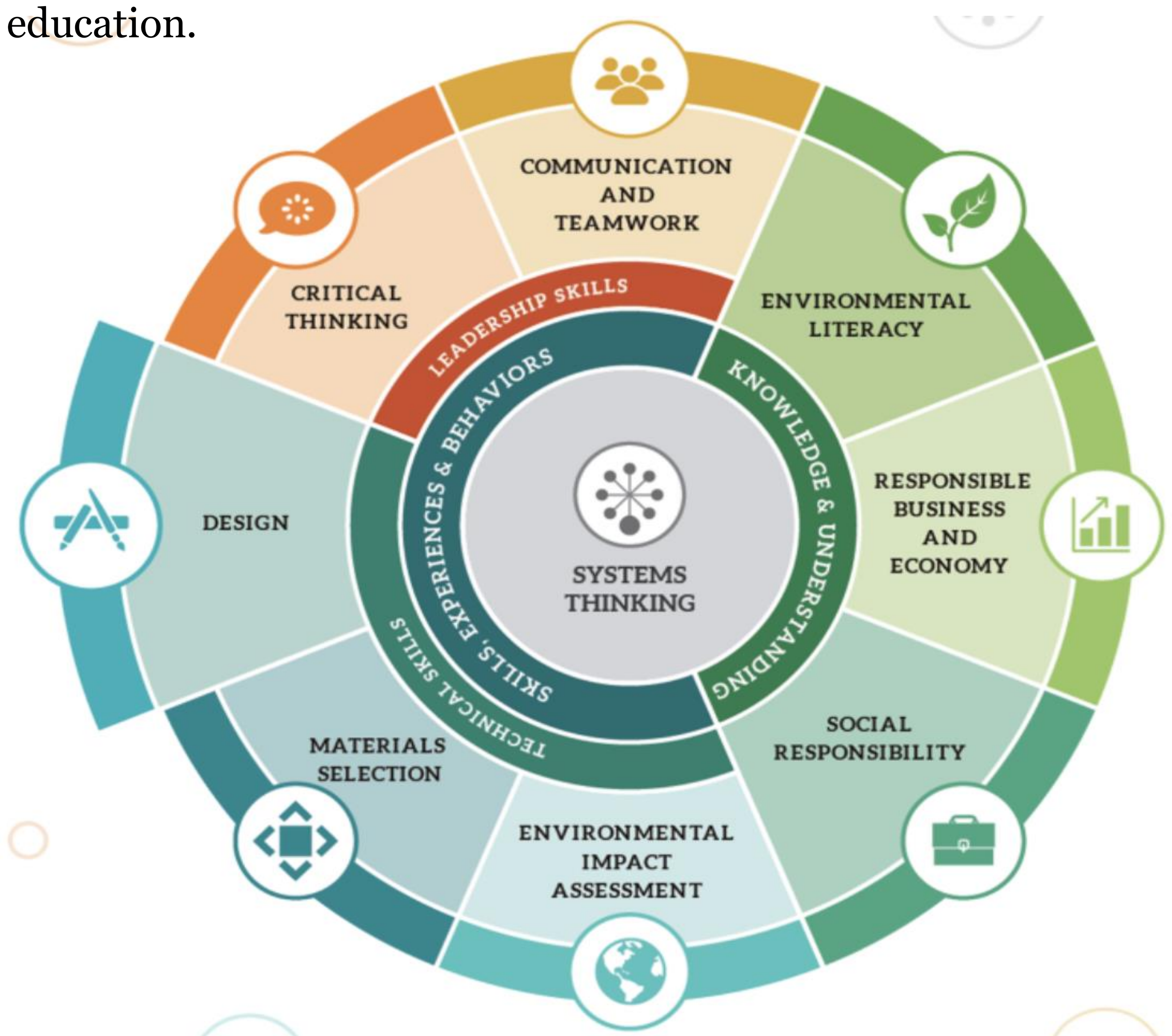
Introduction

The integration of sustainability into engineering is not a new concept but is becoming ever more important for dealing with world issues such as climate change. Finding ways to integrate discussions of sustainability into coursework is imperative. The Engineering for One Planet (EOP) Framework - an environmental, economic, and social optimization paradigm – was integrated into two undergraduate engineering courses as a means to embed sustainability and systems thinking early into engineering education.



- **Introduction to Engineering Design** (First-year course)
  - Traditionally: Students engage in two design projects focused on the engineering design process.
  - Update: Discussions were incorporated that require students to explicitly consider and balance environmental, social, and economic factors within their design decisions.
- **Statics and Solid Mechanics** (Second-year course)
  - Traditionally: Students design a beam using concepts of statics and mechanics of materials, using a single material.
  - Update: Students analyzed and compared beam designs using three different materials—steel, concrete, and wood—evaluating each option based on CO2 emissions, durability, and cost. Encouraging students to reflect on the environmental and economic trade-offs inherent in engineering design.

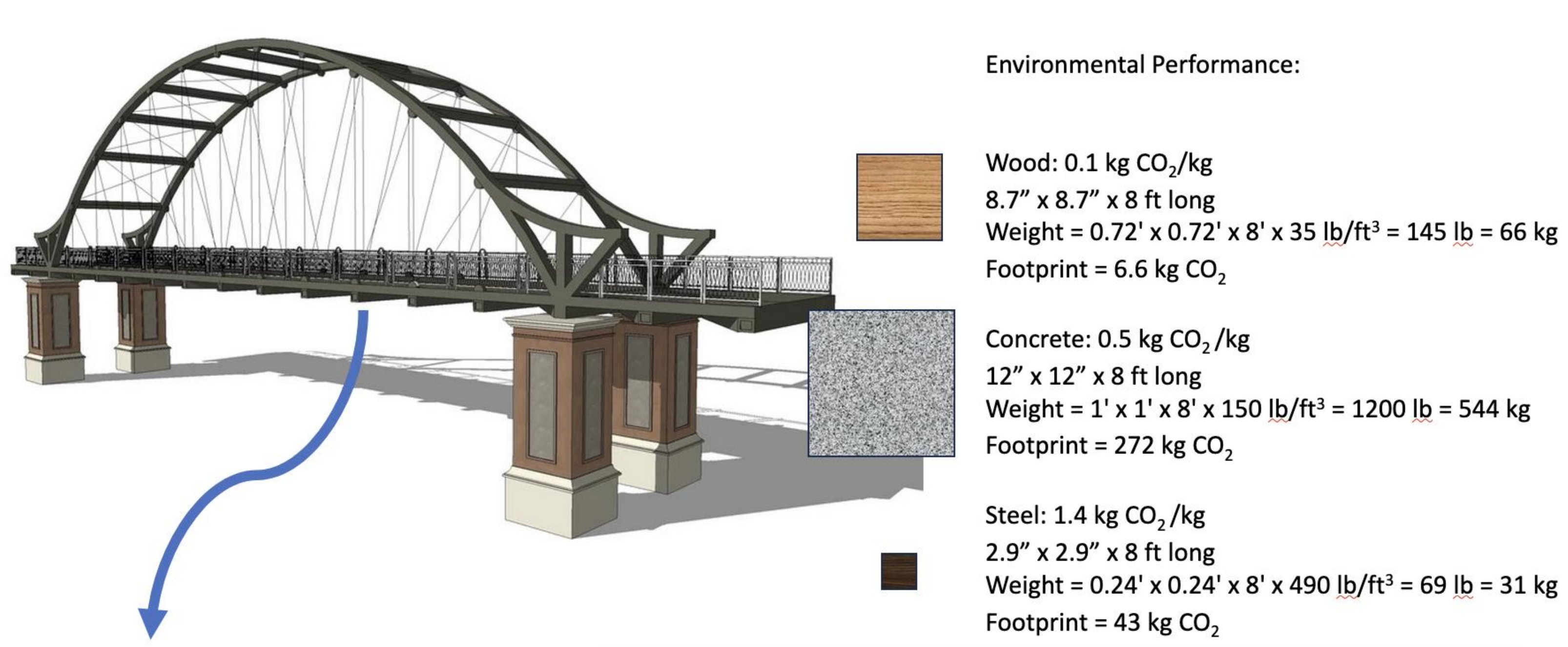
Data collected through pre- and post- surveys was used to assess student understanding of how engineering design decisions can have both environmental and economic impacts.

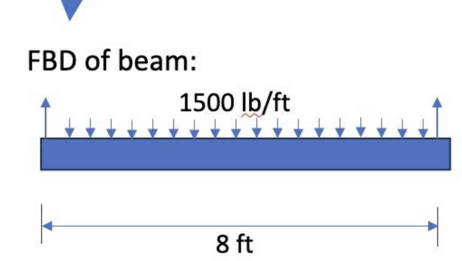
Procedure/Methods

In **Introduction to Engineering Design**, first-year engineering students build and compete in a K'nex car competition. Students were provided with the weight (grams), cost (USD), and carbon equivalent for each piece in the K'nex material kits. Each team then assigned weights to four prescribed merit criteria (vehicle speed, time to construct, cost to build, and carbon footprint). The teams then used these criteria as a systematic way to select which of the three preliminary designs they would use for testing, refinement, and during the competition.

Name:	Weight (grams)	Weight (Kg)	Cost/Unit (U.S. Dollars)	Kg CO2 (eq./ piece)	Measurements (mm)	Quantity
Small Gear (unfixed)	3.06	0.0031	0.61	0.009792	25.4 Dia (14 teeth)	6
Small Gear (fixed)	3.06	0.0031	0.88	0.009792	25.4 Dia (14 teeth)	2
Med Gear	11.2	0.0112	1.69	0.03584	57.15 Dia (34 teeth)	2
Large Gear	10.7	0.0107	0.88	0.03424	88.9 Dia (58 teeth)	1
Crown Gear	24	0.024	3.98	0.0768	130 Dia (82 teeth)	2
Splicer Clip	0.72	0.0007	0.27	0.002304	6 mm thickness	4
Red Ball Half	12.06	0.0121	1.08	0.038592	25 mm Radius	1
Yellow Ball Half	12.06	0.0121	0.39	0.038592	25 mm Radius	1
Light Blue Spacer	0.13	0.0001	0.05	0.000416	3 mm thickness	50
Silver Spacer	0.32	0.0003	0.08	0.001024	9 mm thickness	10
Chain Link	1	0.001	0.15	0.0032	20 mm length	24
Spring Motor	22	0.022	8.03	0.03971	N/A	1
Battery Motor	73	0.073	10.6	0.131765	38 rpm/ 0.162 ft/lbs	1

Mercer University's campus has an iconic pedestrian bridge with which nearly all students can identify. This bridge served as the basis for a project-based learning (PBL) exercise in environmental sustainability in **Statics and Solid Mechanics**. Second-year engineering students were presented with the challenge of evaluating this steel structure and comparing its design to a comparable wood and concrete bridge.





Merit Criteria	Weight	Wood	Concrete	Steel
Cost (C)	10	8	10	3
Strength of Material (S)	10	2	1	10
Durability (D)	10	5	10	10
Environmental Impact (E)	10	10	0	2
Availability of Material (A)	10	5	10	5
	Merit Score	30	31	35

Evaluation and Impact

A pre-survey for **Statics and Solid Mechanics** indicated that, although the students do not have confidence in their ability to define sustainability, they were keenly aware of topics and issues surrounding sustainability. The survey indicated that the vast majority of the students had heard of sustainability with 86.8% (45 out of 52 students) responding in the affirmative.

When asked how well they could define sustainability, responses varied substantially with the majority of students stating that they could only "somewhat" define sustainability, while only a few stated that they could "confidently" define sustainability.

It is noteworthy that all of the students considered environmental sustainability to be either "reasonably important" (38.5%, 20 students) or "extremely important" (61.5%, 32 students), regardless of specialization. Moreover, when asked how engineers could incorporate sustainability into design, responses included:

- Using recycled and renewable materials,
- Designing for durability and longevity,
- Considering the environmental impact of materials and processes,
- Optimizing energy efficiency,
- Reducing waste, and
- Adopting sustainable manufacturing methods.

Preliminary post-course survey results demonstrate that over 85% of students were able to define sustainability within reason or with confidence, indicating successful conceptual development. These findings support the conclusion that sustainability instruction embedded within Statics/Solid Mechanics effectively enhanced students' understanding of sustainability in an engineering context.

Plan for Scaling Up

Future plans include:

- Designing practice problems that require students to implement sustainable design considerations in material selection.
- Implementing sustainability concepts into the second project in the Introduction to Engineering Design course.
- Evaluating students' progression in survey responses from one year to the next to assess retention of information.

References

C. Anderson and C. Cooper, Eds., *The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education*, Portland, OR, USA: The Lemelson Foundation, 2022

Acknowledgement

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