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Redefining Engineering Education: A Sustainable and Inclusive Approach through the EOP Framework

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Redefining Engineering Education: A Sustainable and Inclusive Approach through the Engineering for One Planet (EOP) Framework

Abstract: Sustainability is essential in engineering education, as it equips future engineers with tools to minimize environmental impact and conserve resources, addressing global issues like climate change and resource depletion. An engineering curriculum is a critical gateway to fostering a sustainable and inclusive mindset, integrating principles of environmental stewardship while reinforcing theoretical and practical skills for designing effective, sustainable solutions. In this paper, the flipped-class activities and learning outcomes of developing engineering for one planet (EOP) framework in engineering curriculum is discussed and students' understanding of sustainability, mindset and sense of belonging is evaluated using pre-and post-surveys on their knowledge of concepts, green energy and computing, ethical behavior, environmental and social justice, attitudes and inclusivity.

Introduction:

Engineers are tasked with developing innovative solutions to some of the world's most significant challenges, from saving lives to advancing technology and improving quality of life. However, solving world problems requires collaboration with diverse stakeholders as equal partners. The Serve-Learn-Sustain (SLS) initiative [2] integrates new problem-solving approaches into engineering education to prepare students to tackle sustainability challenges alongside historically marginalized communities. Additionally, increasing the participation of underrepresented students, including first-generation college students, in engineering is vital for sustaining the U.S. research and innovation capacity. However, these students must navigate complex challenges to see themselves as integral members of the field [1]. Teaching sustainable ethical designs and service-based components for undergraduate students helps the next generation in understanding their engineering identity and belonging. In this paper, a curriculum that includes community partnerships helps future engineers to develop an inclusive and innovative engineering mindset. The EOP framework emphasizes three core changes in engineering course design: (1) Sustainable Engineering Ethics, (2) Sustainable Programming, and (3) Sustainable Engineering Design.

Background:

Saginaw Valley State University (SVSU) is engaged in institution-wide efforts to support Diversity, Equity, Inclusion & Justice (DEIJ) for faculty professional development. A DE&I council was established in 1991, and since then, significant progress has been made to foster courageous conversations, provide cultural competence training, and develop service-specific courses to impact the community positively. Recently, SVSU received national recognition in 2022 for its commitment to diversity and inclusion. The engineering faculty members are committed to creating curricula that enhance student learning, reduce implicit bias and sustainable awareness.

Ethics has been taught in engineering programs nationwide since the 1970s, and one of the criteria set by the Accreditation Board for Engineering and Technology (ABET) advocates emphasizes the critical role of environmental responsibility in STEM education. It advocates for integrating sustainability principles into all STEM curricula, not just those with environmental degrees, to prepare graduates for the complex challenges ahead. In [18] initiatives like the Engineering for One Planet (EOP) framework, developed by The Lemelson Foundation and ABET, which guides educational reforms to ensure future engineers are equipped with the necessary skills to address global environmental issues.

At SVSU, engineering ethics is offered as one of the topics in the course titled 'engineering careers and concepts', which is offered to all incoming freshmen engineering students, and in senior year, students are

provided an exposure through their capstone design project. However. Engineering ethics is offered as a general education course for all engineering students in sophomore year. On average, there are 100 students who register for the GenEd and Freshmen 100-level course in an academic year, and 25 students in capstone design course. Exposure to engineering ethics topic is offered to undergraduate students starting their freshmen to senior year in different level of engagement.

Engineering Ethics: The conventional approaches to teaching engineering ethics include using a theory-based approach, which focuses on abstract ethical and moral theories, and a case-based approach, which relates to real-world or fictional scenarios. Many of the case studies used in the course addresses ethical dilemmas, however they are not technologically relevant, potentially leading students to view them as irrelevant to modern engineering challenges [4,5]. Educators have recommended several strategies for increasing student engagement in engineering ethics: involving an industrial expert in bulletin boards, chat rooms, stand-alone ethics course [6], game theory [7], voting on ethical views [8], 3D virtual games [9], and skits [10, 11]. The EOP module will emphasize sustainable designs, ethical responsibility as an engineer to advocate for environmental impact on the planet and aligns EOP framework learning and ABET student outcomes [14].

Programming: Programming skills are increasingly emphasized across age groups and engineering programs to prepare individuals for future careers. However, effectively introducing programming concepts remains a significant challenge in higher education. These skills such as critical thinking, problem-solving, computational thinking and system design [12] are key requirements for programmers. Additionally, aligning programming skills and computational efficiency techniques such as green software [13] is key to computer engineering curriculum. At SVSU many courses in the electrical and computer engineering program require software skills and the gateway course on average has 25 students enrolled in an academic year. The EOP framework will enhance the understanding of green software design with energy efficient modular designs leading to reducing e-waste and encouraging open-source resources.

Capstone Design: Capstone courses, long valued in engineering education for providing students with real-world problem-solving opportunities, were surveyed across North American engineering departments to analyze current practices [15,16]. The findings revealed that mentoring practices primarily support career development and psychosocial functions, with challenging assignments, protection, and acceptance-and-confirmation being dominant. Additionally, faculty background plays a significant role in mentoring effectiveness, while institutional demographics have minimal impact, and ethical understanding is best fostered through coaching, counseling, and role modeling. [17]. Capstone projects, a key component of engineering programs, will integrate both sustainability and Diversity, Equity, Justice, and Inclusion (DEJI) principles to ensure that project designs and materials reflect a broader societal impact.

Curriculum based on EOP Framework:

The courses and the related EOP framework are mapping are shown in Table 1. The three EOP modules:

(1) Sustainable engineering ethics (SEE) module focusses on students focuses on ethical awareness, responsibility, and sustainable practices. Engineers are encouraged to advocate for designs that reduce environmental impact and enhance product longevity. A video skit is directed by senior students that includes a sustainability advocate role. Senior students create SEE video repositories for incoming freshmen students to understand how case studies come alive, and ethical dilemmas are handled.

(2) Sustainable programming (SP) module focusses on energy-efficient, modular programming solutions developed by students, including IoT-based air quality monitoring systems, addressing issues such as emissions and promoting sustainable urban communities in Michigan.

Course Mapping Based on Student Outcome and EOP Framework									
	Skills, Experience and Behaviors						Knowledge and understanding		
		Technical Skills			Leadership Skills				
Courses	Systems Thinking	Environmental Impact Assessment	Materials Selection	Design	Critical Thinking	Communication and Teamwork	Social Responsibility	Responsible Business and Economy	Environmental Literacy
Engg. Careers	**X**	**X**			**X**	**X**	**X**		**X**
Programming	X	X			X	X	X		X
Ethics – Gen. edu	X	X			X	X	X		X
Capstone I	X	X	X	X	X	X	X	X	X
Capstone II	X	X	X	X	X	X	X	X	X

(3) Sustainable engineering design (SED) module focusses on capstone design project which includes evaluating cost, reliability and sustainable solutions for diverse communities. The capstone projects revolve around efficient and sustainable environments using smart technology and data management to enhance quality of life (such as Prosthetic arms, Internet-of-Things Hydroponics system, Assistive toys), reduce carbon footprint (such as home energy distribution system, E-bikes, Solar Powered Induction Charging Electric Vehicle Carport), and a smart pantry for Salvation Army.

Quantitative data from the curriculum redesign measures the EOP framework's effect on students' engineering identity, persistence, and sense of belonging, underscoring the importance of sustainable and inclusive engineering education. The presurvey and postsurvey for each of the course module included (a) General understanding of the course such as ethics, engineering design and programming, (b) specific knowledge of topics covered in the course, such as handling ethical dilemma, stakeholder consideration, understanding social justice, renewable resources, life-cycle assessment, energy efficient methods, e-waste management, virtualization and cloud computing (c) application relevance to the course topic such as ethical decision making, resolving conflicts, problem solving project implementation, innovations, sustainable software development, green computing (d) students' attitudinal questions such as personal commitment and challenges in practicing ethics, sustainability, and green computing. Additionally, the postsurvey also included an additional section of course effectiveness on topics such as ethics, green computing and sustainable designs, active learning format, student learning and engagement.

The EOP modules survey results include students who enrolled for the academic year 2024-2025. There were 50 students from course titled 'engineering careers and concepts', which is a freshmen course offered to all engineering majors. To view the growth of continued exposure of ethics, the freshmen, and capstone I and II courses were surveyed, which comprised of 50, 15, 13 and 5 students in each course respectively. Students' sense of belonging was measured using the attitudinal questions and personal

commitment towards the EOP topics. Based on the responses received, students in the programming course only 7.7% of the students felt they did not have a general understanding of concepts such as green computing and energy efficiency in the post survey in comparison to 12.5% in the pre-survey, which has significantly improved. In the presurvey of students' mindset 50% (half of the student population) disagreed on how innovative technology will continue to improve the sustainability of computing. However, in the postsurvey, about 53.8% of students strongly agreed and 46.2% agreed that innovative technologies will continue to improve the sustainability of computing. In other words, the entire student cohort showed significant improvement towards sustainability mindset.

In the presurvey of ethics module, students' confidence in addressing ethical dilemma in sustainable engineering was 38.5% (strongly agree), while in the postsurvey as shown in Figure 2, the cohort confidence increased by 31.5% demonstrating students' confidence and mindset in ethical considerations required for a sustainable engineering design. Additionally, students also responded to the different teaching methods such as active learning, case study surveys and quizzes, and the most preferred were 60%, 30% and 20% respectively (only strongly agree is listed here).

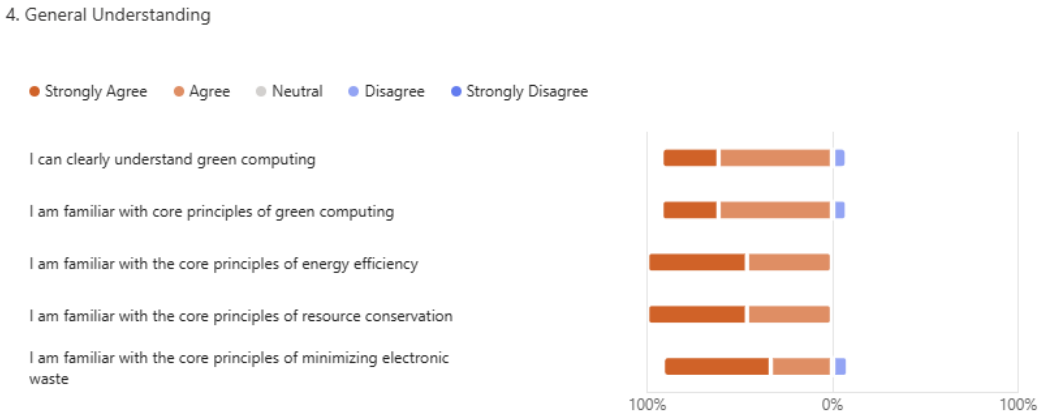

Figure 1. Postsurvey results - General understanding of topics in programming course

Figure 2. Postsurvey results – Engineering Ethics and Sustainability

Conclusion:

In conclusion, the quantitative data gathered from the curriculum redesign underscores the positive impact of the EOP framework on students' engineering identity, persistence, and sense of belonging. The significant improvements in students' understanding of sustainability concepts, ethical decision-making, and green computing reflect the effectiveness of the redesigned curriculum. The increased confidence in addressing ethical dilemmas and the positive shift in students' attitudes towards sustainability highlight the importance of integrating these topics into engineering education. The survey also emphasizes the value of active learning and case studies in engaging students and enhancing their learning experiences. Additionally, the survey suggests that early exposure to ethics during engineering education enables engineers to embrace professional accountability, social responsibility and environmental awareness. Active learning techniques such as role-playing empower students through experiential learning, making sustainability a cornerstone of their professional identity.

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