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Work-In-Progress: Integrating Sustainability Across the Chemical Engineering Curriculum

Dr. Christopher V.H.-H. Chen, Columbia University

Christopher V.H.-H. Chen, Ph.D., is a Lecturer in the Discipline of Chemical Engineering at Columbia University. His teaching and research interests include the application of case- and problem-based approaches to STEM learning experiences; the promise and challenges of online learning; how social and emotional interventions improve engineering education; and preparing graduate students as future change leaders within the academy.

Dr. Courtney Pfluger, Northeastern University

Dr. Courtney Pfluger is an Associate Teaching Professor at Northeastern University. In 2011, began as an Assistant Teaching Professor in First-year Engineering Program where she redesigned the curriculum and developed courses with sustainability and clean water themes. In 2017, she moved to ChE Department where she has taught core courses and redesigned the Capstone design course with inclusion pedagogy practices. She has also developed and ran 9 faculty-led, international programs to Brazil focused on Sustainable Energy. She has won several teaching awards including ChE Sioui Award for Excellence in Teaching, COE Essigmann Outstanding Teaching Award, and AIChE Innovation in ChE Education Award. She also won best paper at the Annual ASEE conference in both Design in Engineering Education Division and the Professional Interest Council 5 (PIC V) for her research in Inclusive Team-based learning. In 2023, she won the Northeastern Inaugural Global Educator Award for her impactful work developing and running international educational programs.

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Abstract

The United Nations 2030 Agenda for Sustainable Development represents a global commitment to addressing the world's most pressing economic, social, and environmental challenges with 17 goals. Specifically, goal 12 looks to address sustainable consumption and production patterns that have many ties to the chemical engineering field. Therefore, teaching chemical engineers to consider and evaluate the impacts of their designs on the environment, individuals, and society is imperative to achieve this Sustainable Development Goal. This need has become so important that ABET has even began to include these considerations in Student Outcome 2, which currently includes the "…consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." In this work-in-progress paper, chemical engineering educators at two large, private, R1 universities present the ways they have introduced and engaged students in considering sustainability, and share sustainability-informed student learning objectives that were assessed via surveys. Specifically, examples across three courses–a Material & Energy Balances course for sophomores, a senior capstone design course, and a senior elective on green chemical engineering–will be used to demonstrate how students learned and applied sustainability values through their engineering design projects.

Students in these courses have or will complete a survey of self-assessed knowledge of the course learning outcomes from each design course before and after the courses. Data from these learning outcome surveys will inform how well the courses addressed sustainability topics, the outcomes for ABET Student Outcome 2, and how the students felt about the applications of these topics in the courses. The following questions will be addressed: (1) How can chemical engineering educators better address sustainability topics in chemical engineering courses? (2) How could chemical engineering educators implement sustainability topics throughout the chemical engineering curriculum to improve students understanding of the need and ability to apply these topics?

Introduction

The United Nations 2030 Agenda for Sustainable Development represents a global commitment to addressing the world's most pressing economic, social, and environmental challenges. This 2030 Agenda consists of 17 Sustainable Development Goals (SDGs) that aim to end poverty, protect the planet, and ensure prosperity for all. Achievement of these goals requires collaboration across different sectors and disciplines–drawing on all professions including engineering–and emphasizes the importance of global cooperation and inclusiveness in achieving sustainable development. Future engineers will need to have global perspective and cultural awareness, to communicate and work effectively with people from diverse backgrounds, in order to contribute meaningfully towards the achievement of the SDGs [1].

Preparing engineers to contribute towards the creation of a more equitable and sustainable world via the UNSDG's will require engineering educators to prepare graduates to work in multidisciplinary teams, able to apply their technical expertise to address social and environmental issues. For chemical engineering in particular, SDG 12, which looks to address sustainable consumption and production patterns, is of particular relevance. Teaching chemical engineers to consider and evaluate the impacts of their designs on the environment, individuals, and society is imperative to achieve this goal. This need for training engineers to consider sustainability has become so important that ABET has even began to include these considerations in Student Outcome 2, which includes the "…consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors [2]."

The teaching of sustainability in engineering is a many-faceted challenge for which there are a variety of existing educational frameworks from which engineering instructors can draw. The Engineering for One Planet (EOP) framework is one such approach that emphasizes sustainable and responsible practices to ensure the well-being of the planet and its inhabitants [3]. The EOP framework specifically connects sustainability learning objectives with social responsibility and global competencies (related to systems thinking, critical thinking, communication, and cultural understanding topics of EOP) to provide engineers with holistic and impactful educational experiences to benefit society. Specifically, global competencies provide cultural awareness and diversity that engineers need to be culturally competent, understand diverse perspectives and consider the global context in their work [1]. This involves acknowledging and respecting cultural differences in design, implementation, and decision-making processes. Developing these competencies provides and supports effective communication which is crucial for global collaboration. Engineers need to be adept at expressing complex technical concepts in a way that is understandable across different cultures and backgrounds.

Global competencies provide a scaffold to work in diverse teams, bringing together individuals with different skills, backgrounds, and cultural perspectives to address global challenges. Providing educational learning opportunities in social responsibility through ethical decision-making is important as it aligns with ethical considerations by promoting sustainability and responsible resource use [4]. Social responsibility involves engaging with communities to understand their needs and concerns. Engineers should actively involve local communities in the design and implementation of projects, ensuring that solutions meet their requirements and respect their cultural values. Engineers should prioritize environmentally sustainable practices, considering the long-term impacts of their projects on ecosystems and natural resources.

Global competencies and social responsibility are particularly important for chemical engineering undergraduate students to understand for several reasons. Chemical engineers often work on projects and processes that have a significant impact on society and the environment. Understanding their social responsibilities helps them make ethical choices in their work, prioritizing safety, sustainability, and the well-being of communities. Chemical engineering processes can have far-reaching environmental consequences. By incorporating global competencies and environmental responsibility into their education, students can contribute to sustainable practices, reduce pollution, and minimize the depletion of natural resources [5].This also plays into today's interconnected world, engineers often collaborate on international projects or work for multinational companies. Global competencies enable chemical engineers to communicate effectively across cultures and understand the global implications of their work [6].

Part of the challenge that we see of teaching sustainability in chemical engineering is two-fold: (1) there is a need for more in-discipline examples of sustainability in chemical engineering across the curriculum–with these considerations only potentially in capstone design, if that–and (2) the complexity of existing frameworks in how they can be relevant to the teaching of chemical engineering. Thus, we have combined the values of the UNSDGs, Engineering for One Planet, the Professional Social Responsibility Development Model, and Global Competencies frameworks into three compact Sustainability-in-Action Elements (SAEs) to help other chemical engineering educators begin to incorporate these elements into their courses and curricula:

- *Sustainability Awareness*: Students will be able to describe and appreciate different cultures, values, and perspectives; the sources of pollution, emissions, and climate change; and the need for more sustainable practices.
- *Evaluating Impact*: Students will be able to determine the impacts on society, environment, etc. of an engineering action.
- *Taking Action*: Students will be able to apply their sustainability awareness and ability to evaluate impact to design an engineering solution that creates positive environmental and social value.

We show how the SAE objectives connect to the EOP and PISA Global Competencies frameworks in Figure 1.

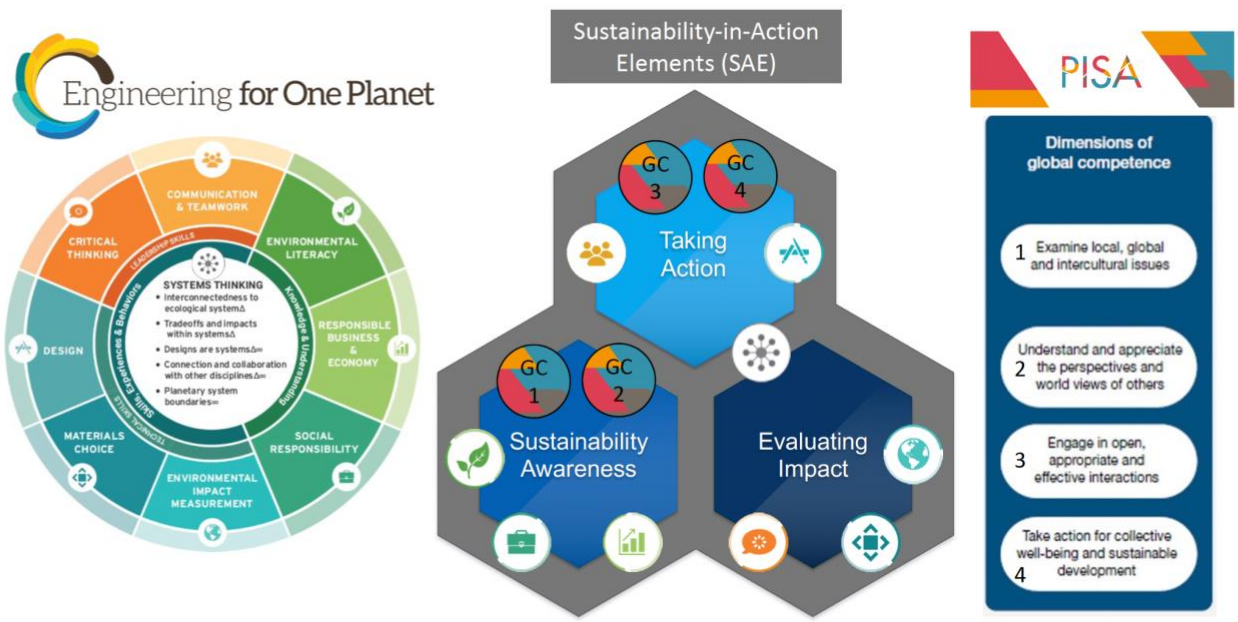

Figure 1: Sustainability-in-Action Elements (SAE) objectives connected with the Engineering for One Planet (EOP) Framework (left [3]), and PISA Global Competencies (adapted, right [7]). Each of the EOP topics and Global Competence Dimensions generally fit into one of the three SAE objectives, with the EOP topic of Systems Thinking placed in both Evaluating Impact and Taking Action.

These broad elements help to frame how chemical engineering students can develop sustainability concepts and skills applied to engineering design throughout the scope of their undergraduate (or graduate) curricula. To help demonstrate how the SAE objectives can help with the integration of sustainability content into chemical engineering courses, we describe example courses that appear in different parts of our curricula, at two different universities (Northeastern University and Columbia University), and how these curricular objectives are targeted within each. These cases are used to show how other chemical engineering educators address the following questions: (1) How can chemical engineering educators better address sustainability topics in chemical engineering courses? (2) How could chemical engineering educators implement sustainability topics throughout the chemical engineering curriculum to improve students' understanding of the need and ability to apply these topics? We follow these examples with a description of our planned assessment to complete this work-in-progress paper.

Description of Courses

To help demonstrate how we are able to integrate sustainability across the chemical engineering curriculum, we present how we target the SAE objectives across three courses at Columbia University and Northeastern University, two private, R1 universities: a Material & Energy Balances course that serves as the first technical course in the major, a senior capstone design course, and a senior/graduate-level elective on green chemical engineering.

Material & Energy Balances (Columbia University). Material & Energy Balances is the first course students take in the major, and, often, in engineering generally at Columbia University. Enrollment averages 30 students each year, composed of a mix of sophomores and transferring juniors (in their first term at the school). Students in the course are residential learners, with no remote option given to students for learning. The course has been taught in a flipped structure since Fall 2020, with the current instructor having taught the course each fall term since 2018.

The course focuses primarily on mass and energy balances, and their application to analyzing process flows, and has the following course goals:

1. Students will be able to explain how chemical engineers approach problems and what roles chemical engineers serve across industries.
2. Students will be able to propose quantitative solutions to a variety of complex problems using approaches familiar to chemical engineers, such as balance equations.
3. Students will be able to critique solutions proposed by peers and determine the qualities of stronger answers through a chemical engineering lens.

Though the course is not primarily focused on sustainability, many of the students come in with sustainability as a strong interest, which is fostered through pursuit of learning objectives 1 and 3. Four course elements were relevant towards helping students engage with the SAE objectives: flipped classroom, community contributions, homework, and case studies and design project (as mapped against the SAE objectives in Table 1). Since this is an introductory course in the discipline, however, the depth of engagement with these objectives are relatively low. We describe how these course elements map to the SAE objectives below.

Table 1. Mapping of MEB Course Elements to SAE Objectives

Course Element	Sustainability Awareness	Evaluating Impact	Taking Action
Flipped Classroom	X	X	–
Community Contributions	X	–	–
Homework	–	X	–
Case Studies & Design Project	X	X	X

Flipped Lectures. Flipping (or inverting) the classroom can take many forms in practice, but generally entails making “events that have traditionally taken place *inside* the classroom now take place *outside* the classroom, and vice versa [8].” For this course, flipping meant taking lectures that were given in-class when the course was not flipped, and recording them for students to be able to access via Canvas before class. Class time was then replaced by a variety of other group learning activities (e.g., group problem solving, peer-led instruction) during synchronous, Zoom meetings. Evaluating the impact of chemical processes is a natural part of the MEB curriculum (e.g., evaluating efficiency, atom economy). Sustainability awareness content was added to the course during the recording of the lectures to target sustainability awareness, and to provide examples that were relevant to students. Examples of this include a sample discussion of washing soda production, and how the decisions around whether to synthetically produce washing soda (via the Solvay process) or mining trona for the material is a more sustainable decision; and a history of how chemical engineers are tied historically to the production of energy (i.e., liquid fuels), and how chemical engineers could create a more sustainable future.

Community Contributions. Participation would be a more common name for this course element. However, “community contributions” was strategically chosen to demonstrate that this element of the course was more than just attendance in the course and in-class participation to include other ways that students could contribute to the communal learning in the course and receive recognition for this work. Through the inclusion of online discussion forums into this course element, students were able to explore and report on how course content was relevant to their own interests as a developing chemical engineer, often relating to sustainable topics. These helped to foster students' awareness of sustainability, and having students share how course material related to their own engineering values allowed for the development of student appreciation for different cultures, and perspectives.

Homework. Traditional problem sets were used in the course to evaluate technical skills and impact evaluation methods taught in the course. This includes the determination of reactor and separator (or general process) efficiency, the calculation of atom and process economy measures, and reporting of safety considerations. Homework problems were written in a way to help students connect these technical calculations to impacts on people and the environment.

Case Studies and Design Project. Case-based instruction is a pedagogical approach common in law, medicine, and business, but is relatively less common in science and engineering [9]. Cases were implemented for MEB at a variety of time scales; cover a variety of sectors (e.g., commodity chemical, energy and the environment, biopharmaceutical); and place students as chemical engineers in a variety of roles (both traditional and non-traditional). The shortest of these cases were run as in-class activities (~50 minutes) that displaced time that was previously allocated to lecture (typically instructor-guided problem solving or example applications of course concepts). Other cases were assigned as homework (weeks-long)–with case-based problems replacing additional problems on a problem set-–and as a final design project (1 month long). By placing students as the decision-makers in the story, students are forced to consider their engineering decisions holistically, leveraging their sustainability awareness and ability to evaluate impact to determine how to take action. This is demonstrated most in a final design project, where students design and evaluate a proposed engineering project and give an up or down decision. In past years, topics for the final project have included evaluation of green hydrogen and carbon sequestration projects.

Chemical Process Design Capstone (Northeastern University). Capstone at Northeastern University is a project-based course where teams design a chemical process for a product or system with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. All projects require applications of chemical engineering curriculum such as material and energy balances, kinetics, thermodynamics, and mass and heat transport and using the engineering design process to come up with a business plan, consider multiple designs, and come up with a final detailed design process. The design is validated with proof-of-concept data from a prototype, experiments, or simulation of the process to show the design is feasible and use that data to improve the design. Teams present, in multiple formats, the progress and final design to peers and the greater chemical engineering community, and also submit multiple progress reports that turn into the final design report at the end of the semester. Project topics are specifically selected to address real-world sustainability and environmental issues that have valuable positive societal impacts. Example project topics include Polylactic Acid (PLA) production from anaerobically treated food waste, creating sustainable textiles from Mycelium Mushrooms, Design of a Thermal Storage solution for Vertical Farm for an Indigenous community in Northern Canada, Cost Effective Removal and treatment of microplastics in municipal wastewater, Sustainable Energy Production of Brewers Spent Gains (BSG) from Beer Brewing Process, and PFAS destruction in Southern Maine Regional Biosolids Processing Facility. These course elements are mapped to the SAE objectives in Table 2, requiring much greater depth with each of the SAE objectives due to Capstone's place as the end point of the undergraduate curriculum. Each of the course elements are described in greater detail below.

Table 2. Mapping of Capstone Design Course Elements to SAE Objectives

Course Element	Sustainability Awareness	Evaluating Impact	Taking Action
Teamwork & Individual Assignments	X	–	–
Progress Memos	X	X	X
Feasibility Memo	X	X	X
Business Plan	X	X	X
Detailed Design	-	X	X
Final Design Report	–	X	X

Teamwork & Individual Assignments. Teamwork and collaboration are a very important part of this course and link to the EOP and Global competency frameworks through the SAE objective of Sustainability Awareness. As a result, teams develop a detailed team agreement or charter as well as fill out individual and peer team surveys on team performance. After each milestone, students evaluate themselves and teammates using a five-point behavioral scale on five criteria: (a) contributing to the team; (b) interacting with teammates; (c) keeping the team on track; (d) expecting quality from the team; and (e) having relevant knowledge, skills, and abilities. Results from these surveys may be used to determine or adjust grading of individual students on the final report, to identify teams who could benefit from instructor intervention and to assess overall teamwork effectiveness of the students. Individual assignments were given in the form of LinkedIn learning modules on Project Management, Sustainability in Design, Teamwork Foundations, and Unconscious Bias and Inclusive Leadership. These modules include video instruction and quizzes to ensure understanding of these topics.

Progress Memos. Each group is expected to have a weekly progress update memos that helps provide project management and planning by discussing current status of project, concerns in the current process design, how they will be addressing them going forward, and team roles and responsibilities. Each memo is important because it serves to focus on communication to the tasks at hand and towards the topics specifically addressed in the upcoming report. These memos included implementing inclusive team practices and sustainability topics taught in lectures and discussed how they were implemented into the projects.

Feasibility Memo. The feasibility memo discusses project foundations such as the problem that is to be solved, why this problem is of global or environmental interest, initial ideas to solve this problem, and the significance of resolving this problem. A focus on what the real issues surround their project topic and must address how their proposed design goals and decisions will take into consideration public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. The teams need to perform research and make decisions on how their project topic currently affects these issues and how their designs will better their impact. This is an important foundation step in defining their problem and generating solutions for design projects.

Business Plan and Base Case Design. The business plan report provides background relevant to the project problem and science of the process. It includes a mission and Diversity, Equity, and Inclusion Statement (DEI). As part of the business plan, the teams must do a market analysis to help figure out needs and costs of the product or process, who makes it now/ what alternative is being used, how much is produced, how much do is sell it for, what makes the teams design or product different from what is currently on the market, and how much needs to produce to meet the market demand. The project teams are also required to come up with Base Case Designs that define design goals and criteria, rank how important each goal is, and come up with multiple design options using block flow diagram (BFD) and process flow diagram (PFD). The elements adding to this course, that is not typically taught in traditional capstone courses is that the student teams are asked to take into consideration sustainable design criteria such as sources and life cycle analysis of raw materials, amount of energy, water, and resources needed for their proposed design process, and product and/or process end of use cases, such as product use, energy and resources needed to use it, shelf-life or process-lifetime, by-products, waste management, and reduction of environmental and social effects. These considerations in the development of their process designs help connect to their awareness of how sustainability can be implemented into a design, evaluate how their design goals and considerations can have an impact on sustainability, and use those goals to execute them into their final designs.

Detailed Design. The detailed design provides the details and justifications of the process that is being designed. Details of the design include overall Process Flow Diagram (PFD) with heat integration, stream flows, and compositions in the process, along with details on process conditions and sizing of each unit operation. Another important component is process controls and safety consideration to ensure safety, health, and environmental codes and laws are complied with. These include a Piping, and Instrumentation Diagram, a SDS Summary Sheet, and a HAZOP analysis. Lastly, proof of concept analysis and testing detailing simulated or experimental data to justify, enhance, or re-evaluate design choices. The proof-of-concept data is used to evaluate their designs sustainability impact on energy, water, carbon, and waste streams. The designs are then modified to improve upon these conditions to less their environmental and societal impacts.

Final Design Report. The final report combines the business plan and base case design and detailed design content and includes economic analysis of the process. This is where the design details and business plan come together to determine if the project is economically feasible to be built and sold on the market. The designs of their projects are assessed for thorough evaluations and implementation of environmental, societal, and economic design goals set earlier in the feasibility memo stage of the project. Overall, this chemical engineering capstone design course builds upon traditionally capstone design courses to add design goals and considerations of Sustainability-In-Action Elements. The addition of these elements allows for critical thinking and implementation of sustainability in their process designs and allows for a richer educational design experience.

Green Chemical Engineering Elective (Columbia University). This Green Chemical Engineering & Innovation course is an elective for chemical engineering senior undergraduates and graduate students that can be used towards the program's "Climate Solutions" concentration. Enrollment was around 30 students for the first two terms the course was offered (Spring 2023 and Spring 2024). All students attended in person, with no option offered to attend the course remotely.

The course was designed to facilitate students to be able to do the following by the end:
1. Describe the tenets of green chemistry and their pertinence to chemical engineering practice.
2. Explain how Systematic Inventive Thinking (SIT) and green chemistry constrain the design process and can help improve innovation.
3. Apply green chemistry approaches to the design of a more sustainable product/process.
4. Evaluate the environmental, business, and social impacts of a chemical product or process.

As a senior/graduate-level elective in our Climate Solutions concentration, the course has a strong emphasis on sustainability and is able to draw on the previous knowledge and skills that students have developed throughout the rest of the undergraduate curriculum as a basis to bring these sustainability considerations into action. Five course elements were relevant towards helping students engage with the SAE objectives: classroom participation, case studies and guest speakers, community contributions, homework, and a final green design project. These course elements are mapped to the SAE objectives in Table 3, and are described in depth below.

Table 3. Mapping of Green Chemical Engineering Course Elements to SAE Objectives

Redesign Element	**Sustainability Awareness**	**Evaluating Impact**	**Taking Action**
Course Participation	X	X	X
Case Studies & Guest Speakers	X	X	X
Community Contributions	X	X	–
Homework	–	X	X
Green Design Project	–	X	X

Course Participation. As a course that implements active learning in the lectures, active participation by students is essential in their learning. As such, we employ the method recommended by Tharayil *et al.* to mitigate student resistance to active participation in this masters-level course by grading participation, developing a routine about engagement, and encouraging non-participants [10]. Each class starts with a product, process, or firm which students must decide is or is not green, and how or whether they create value. Throughout the class there are typically 1 or 2 more activities in which students evaluate or propose a design based on the green chemical engineering principles discussed. Participation is graded with a mix of in-person measures (e.g., attendance, submissions to PollEverywhere, number of questions asked or comments given), along with pre-class activities (e.g., completing a poll before class about a case).

Case Studies and Guest Speakers. Case studies are used in this course to help students engage with guest speakers who share their experience from industry of taking their sustainability values into engineering actions. For most guest speakers, case studies are written on a problem (current and unsolved; or historical and resolved) that the speaker has encountered in practice and places the students into the role of recommending a solution. This requires students to understand and evaluate the values and goals of the firm/speaker and present a sustainable solution that fits those needs. Cases have been written about startups doing carbon capture and utilization, hydrogen production, and innovative reactor design for the course.

Community Contributions. As a means of recognizing individual student curiosity and encouraging them to share their curiosity with the class, students engaged in ongoing community contributions activities throughout the term that was 30% of their final grade. This was separated from attendance to demonstrate how this was more akin to building a professional network and perspective than mere classroom participation. As the space of green chemistry and engineering is quite broad, this course element helped to facilitate students to deepen and personalize their learning while the course lectures and assignments focused more on breadth within the subject. Based on an individual learning goal set by the students themselves, each student was asked to contribute to the ongoing community conversations by: (1) tracking and sharing about particular topics within green chemistry and chemical engineering of interest to you; (2) preparation and submission of reading responses that correspond with these interests and your goals for the course; (3) participation in general online discussion boards for the course; and (4) short presentation of papers, articles, or other resources you had found during your own development that connect to the class at large. Some of these contributions were done as individuals and others as teams. Students were encouraged to follow others with similar interests and to comment on readings shared throughout the course.

Homework. Homework assignments in the course provided practice on individual skills prior to the final design project. As the final project focused on taking action, an emphasis in these assignments was placed on developing awareness and evaluating impact (with some simple design practice problems). Some homework were individual assignments, and others group-based depending on the skills selected for practice. Assigned problems focused on sustainability metrics and their appropriateness to select industries, and how to weigh environmental, social, and economic considerations against technical constraints in their evaluation of a design.

Green Design Project. As a capstone to the course, student teams design a green chemical product and/or process that they pitch to the class. Students are required to draw from across the technical content of the course to describe the product/process their team proposed; make a case as to how it is innovative and leverages the tenets of green chemistry/engineering; and report on the business, environmental, and social value created by the innovation.

Planned Assessment

Assessing the Sustainability-in-Action Elements in these courses was done by combining two validated assessments, one on global competencies and the other on social responsibility. These assessments mapped to the EOP framework, specifically through the pedagogical approaches to working in diverse teams, understanding cultural perspectives in addressing global challenges, and providing educational learning opportunities in social responsibility through ethical decision-making. This mapping aligns with ethical considerations by promoting sustainability and responsible resource use.

The first validated assessment we drew from is the OECD Program for International Student Assessment (PISA) global competency framework. This framework has four dimensions: (1) the capacity to examine issues and situations of local, global and cultural significance; (2) the capacity to understand and appreciate different perspectives and world views; (3) the ability to engage in open, appropriate, and effective interactions across cultures; and (4) the capacity to take action toward sustainable development and collective well-being [7]. Figure 2 shows how these four dimensions were derived from students' global understanding. The PISA global competence framework is used for this project because it allows for the assessment of the Sustainability Awareness SAE objective.

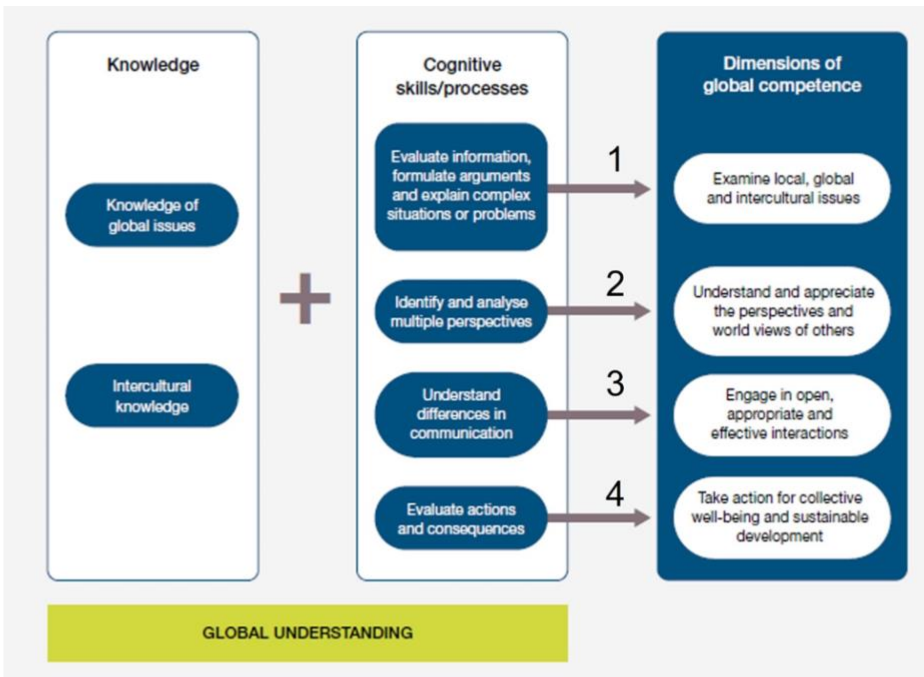

Figure 2. PISA cognitive test of global understanding and the four dimensions of global competence [7].

We drew from a second validated assessment–the Professional Social Responsibility Development Model (PSRDM)–to assess students' inclination to social responsibility actions, shown in Figure 3. The PSRDM uses three realms to address the development of social responsibility: Personal Social Awareness, Professional Development, and Professional Connectedness. The Personal Social Awareness realm describes the development of feelings of moral obligation to help others separate from one's professional identity. The Professional Development realm describes the development of professional abilities, with a focus on how those abilities could be used to help others. The Professional Connectedness realm describes how a moral obligation to help is tied to one's professional identity and how engagement in service influences that feeling of obligation. Canney et al. used the PSRDM to develop the Engineering

Professional Responsibility Assessment Tool, which we use in a way to assess the Taking Action SAE objective [11].

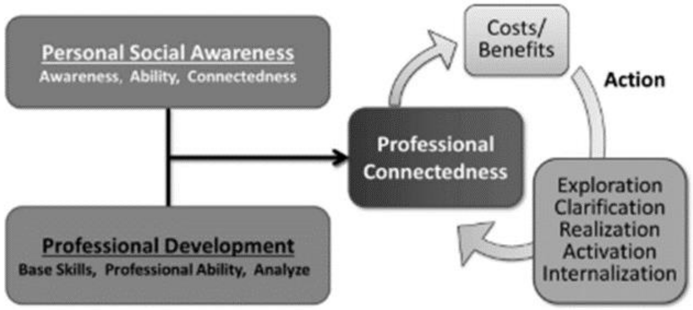

Figure 3. Professional Social Responsibility Development Model [11].

In this study we plan to use questions from both the PISA Cognitive Test for Global Understanding (questions to assess Global Competencies), and the Engineering Professional Responsibility Assessment to study the students' perception of social responsibility and global awareness in our SAE context before and after completing these courses. The PISA questionnaire allows for assessment of sustainability awareness and taking action objectives, and the PSRDM helps to assess taking action, also. Technical course assignments will be used to assess how students evaluate impact. How these approaches map to the SAE objectives are shown in Figure 4.

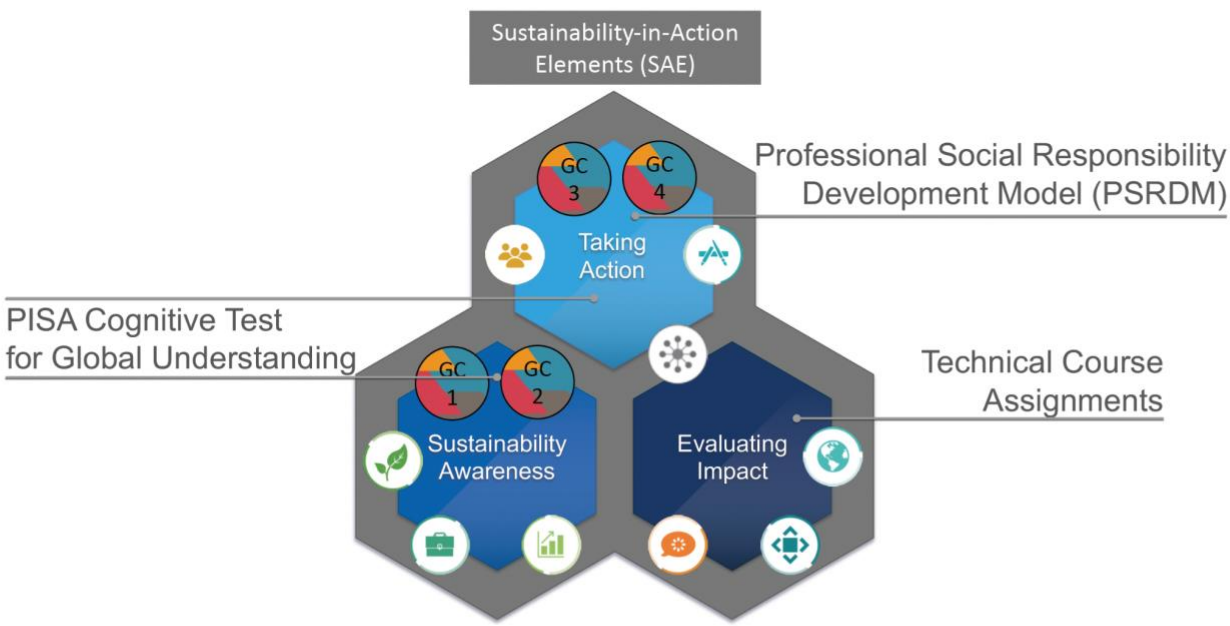

Figure 4: Mapping of assessment approaches to the SAE objectives.

Discussion

These example courses have run multiple terms with the SAE objectives integrated into these courses and the described surveys have been used to gather preliminary data for the Material & Energy Balances course from Fall 2023. Students will be surveyed in the Capstone and Green Chemical Engineering courses in the Spring 2024 term. Looking at these data altogether will help us continue to refine and target the SAE objectives within these courses, and across courses within the chemical engineering curriculum.

In our work-in-progress paper, we sought to address two questions: (1) How can chemical engineering educators better address sustainability topics in chemical engineering courses? (2) How could chemical engineering educators implement sustainability topics throughout the chemical engineering curriculum to improve students' understanding of the need and ability to apply these topics? Although our study is ongoing, we hope that the Sustainability-in-Action Elements and examples in courses that we have shared will help our colleagues see how they can also bring sustainability into their chemical engineering courses, independent of position of these courses within their curricula. We hope that this will lower the barrier for our colleagues to start to incorporate these broad elements–even in small ways–into their classrooms. With the data we are collecting, we plan to demonstrate how effective these approaches are in helping students develop the abilities necessary to foster new engineers who will help us create the equitable, and sustainable future envisioned by the UNSDGs.

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