frontiers | Frontiers in Education

TYPE Brief Research Report
PUBLISHED 22 May 2024
DOI 10.3389/feduc.2024.1396377

OPEN ACCESS

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RECEIVED 05 March 2024
ACCEPTED 09 May 2024
PUBLISHED 22 May 2024

CITATION
Chakraborty S, Kalhori SK, Gonzalez Y, Mendoza J and Galatro D (2024) Student perception of sustainability in industry: a case study in an undergraduate petroleum processing course.
Front. Educ. 9:1396377.
doi: 10.3389/feduc.2024.1396377

Student perception of sustainability in industry: a case study in an undergraduate petroleum processing course

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Research demonstrates a predominantly negative public perception of the oil and gas (O&G) industry, regardless of initiatives created to minimize the environmental impact. This might be attributed to a lack of open communication and debate spaces where these initiatives are learned and discussed. To test our hypotheses within a university setting, a major revamp of the course "Petroleum Processing" in our university was implemented, where sustainability concepts and open discussion were assimilated into the lecture content. Pre- and post-surveys were conducted to assess students' perceptions regarding sustainability in the O&G industry before and after the course. Perceptions remained unchanged following course delivery. However, students believe they are more informed about the sustainability approaches implemented.

KEYWORDS

SDG 9: industry, innovation and infrastructure, course revamp, oil and gas (O&G) industry, students' perceptions

1 Introduction

The oil and gas (O&G) industry has been traditionally perceived as incompatible with transparently addressing and successfully incorporating green technology and sustainability initiatives into their supply chain operations (United Nations, 2017, 2023; Dadd et al., 2023), with significant discrepancies observed even today among companies and geographies (Okeke, 2021; CAPP, 2023). An analysis of 150 annual reports of 15 O&G firms based in Europe, America, and Asia led Okeke (2021) allows us to conclude that European companies have typically put more emphasis on environmental, social, and economic components of environmental sustainability than their American and Asian counterparts. This trend may be attributed to the regulatory pressure on implementing sustainability measures and initiatives to enhance societal awareness toward fulfilling such core sustainability practices (Okeke, 2021). Nevertheless, public perception of the O&G industry continues to reflect distrust and dislike, which may potentially arise from its repeated non-compliance regarding environmental and social issues (Theodori and Jackson-Smith, 2010). A survey conducted by the consulting firm Ernst & Young found that over half of the 1,200 surveyed teenagers responded that the O&G produced presently is "not worth the environmental impact" (Rassenfoss, 2019). When compared to the public perception of various other industries, the survey revealed that the respondents distrusted industrial giants almost at the same level as healthcare; this distrust is only surpassed by the banking and pharmaceutical sectors.

Despite significant contribution toward climate change, the O&G industry continues to, and likely will for the foreseeable future, remain a key player in the global energy pool (Dewar et al., 2022). As such, several major O&G players worldwide are mandated to develop and implement integrated sustainability initiatives and strategies to maintain their operating licenses while global energy trends shift toward greener measures. Such strategies primarily focus on (i) reducing operations-based emissions by piloting and deploying commensurate technologies that monitor waste/exit streams, (ii) research initiatives to develop novel mitigation technologies, and (iii) diversifying toward the low carbon energy sector (Dewar et al., 2022). However, commensurate quantification of these measures' impact(s) remains challenging, as several more longitudinal indicators are required. Moreover, the public may also be unaware of novel transformative measures undertaken by the O&G sector. We hypothesize this occurrence because of: (i) a lack of open communication, and failure to adequately highlight the spectrum of "green" initiatives undertaken by the O&G sector, and (ii) a lack of spaces where people may debate about the perceived/actual benefits/drawbacks of these measures.

To test our hypotheses within a university setting, a major revamp of the elective course "Petroleum Processing" in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto was implemented, and key sustainability concepts, such as integration between biorefineries and petrochemical plants and hydrogen production, were assimilated into the lecture content. A succinct simplified Life Cycle Assessment (LCA) comparison between different processes/industries was also performed. Students were provided with a space to discuss these impactful environmental/sustainability initiatives and offer opinions. Students' perceptions were recorded using a pre-survey at the beginning of the semester and a post-survey at the end of the course. This curriculum transformation exercise supports preparing our engineering students and future leaders to tackle the challenges in the sustainable development goals (SDG), particularly SDG 9 (industry, innovation, and infrastructure), as the revamping of our course aligns with encouraging students to actively upgrade industries by promoting innovative sustainable technologies and ensuring their access to information.

This article is structured as follows: section "2 Materials and methods" details the methodology used to record and assess students' perceptions regarding sustainability in the O&G industry before and after course delivery. Section "3 Results" presents and discusses the results we obtained from the conducted surveys. Section "4 Conclusion" discusses key conclusion that can be drawn from the survey results as well as future directions for this research.

2 Materials and methods

This section describes our sustainability integration strategy, and the framework used to assess students' perceptions.

2.1 Original course description and structure

CHE 451 – Petroleum Processing is a fourth-year elective course offered to chemical engineering undergraduates. Typically, the course is delivered in-person during the fall semester and has 15–25 students enrolled annually. The course aims to examine the operations of the oil refining industry from a primarily macroscopic standpoint via block flow diagrams (BFDs), while its main learning outcome is for students to obtain a generic overview of key petroleum processing operations, products, their economic importance, as well as major safety and environmental aspects employed in oil refining. Prior to implementing the revamp described in this work, the course traditionally included 16 lectures (designated as L), as summarized in **Table 1**. The grading scheme included a midterm (worth 25%), two assignments (A1 and A2), each worth 10%, a final project worth 20% (an essay on refineries for the future), and a final assessment worth 35%. The lectures had only one module discussing the environment and safety aspects and the course content was predominantly industry focused, rather than environment/climate-change focused.

2.2 Sustainability integration strategy

The imminent need to incorporate sustainability initiatives into traditional engineering curricula has been an issue addressed by several prior researchers. Some novel practices reported in the literature are (i) the embedding of sustainability-based perspectives into courses, (ii) careful design of new courses, and (iii) providing pathways for students to specialize and gain expertise in sustainable development (Ashraf and Alanezi, 2020). Out of these, the design and introduction of new courses, which aim to educate and empower students toward the ever-changing global perceptions and needs, remains the most popular pedagogical pathway of choice. Implementation of these strategies has recently revealed that (i) most such studies neglect the learning process in favor of assessing learning outcomes at a specific timeframe (a form of testing bias); (ii) and students' perceptions of sustainability may often approach those of their instructors throughout the learning experience, which may be viewed as a sign of conformance (van Mierlo and Beers, 2020). We believe that this convergence of ideological stance is to be avoided, and suitable learning environments should be devised, where students may develop their individual, different stances on the subject matter, which may be different from their fellow students and instructors. Thus, we aimed to develop and execute a course revamp in an unbiased, minimally disruptive fashion, to assess any tangible shift in student perception accurately. Therefore, this led to the design of a sustainability integration strategy to address the following research questions: (i) what are the current problems students perceive with the O&G industry? and (ii) how can a teaching team facilitate spaces for

TABLE 1 Original and revamped CHE 451 lectures (L) and assignments (A).

Code	Original CHE 451	Revamped CHE 451
	Description	
L1	Introduction to petroleum processing	Introduction to petroleum processing
L2	Refinery feedstocks and products	Petroleum products and test methods
L3	Refining processes	Processing operations in a petroleum refinery
L4	Crude distillation	Lubricating oils
L5	Coking and thermal processes	Petrochemicals
L6	Catalytic cracking	Product blending
L7	Hydroprocessing and hydrotreatment	Supporting processes
L8	Catalytic reforming and isomerization	Alberta crude oil
L9	Alkylation	Safety and environmental issues
L10	Product blending	Biofuels in a petroleum refinery
L11	Supporting processes	Hydrogen production
L12	Alberta crude/heavy crude oil	The refinery of the future
L13	Lubricating oils and blending stocks	–
L14	Petrochemical feedstocks	–
L15	Environmental and safety aspects in refining	–
L16	Refinery of the future	–
A1	Mass/volumetric balance in a refinery	Mass/volumetric balance in a refinery
A2	Safety aspects in a refinery	Safety aspects in a refinery

open discussion regarding industry practices and future directions for the energy transition? As a first solution, we executed a paradigm shift on the learning process by (i) aiming to deliver more comprehensive lectures that describe the environmental impact of oil production, refining/petrochemical supply chain operations, and actions implemented toward remediating it; (ii) facilitating in-class discussions comparing the LCAs between oil and biorefineries, as well as blue/green hydrogen production; and (iii) facilitating open discussions for students to debate the pros and cons of specific sustainability-related issues.

2.2.1 Lectures and assignments

The modified lectures for CHE 451 are summarized in Table 1.

While lectures L1–L3 maintained a similar structure as those being offered previously (ensuring minimal disruption and some conformity with previous content), the environmental impact of oil refining and petrochemical plants operations were incorporated in L4–L8, accounting for 15% of the course content. L7 was restructured to have 60% of the content discuss carbon capture initiatives and hydrogen sulfide management in refineries. L9 was dedicated to describing in detail potential safety issues and risks related to oil refineries, potential environmental issues, mitigation paths, and a summary of incidents experienced, and lessons learnt by the global O&G industry. L10 was a completely new lecture which introduced biorefineries, highlighting feed characteristics, operation and maintenance, and integration with existing oil refineries and/or petrochemical plants. Likewise, another novel lecture, L11, introduced hydrogen production in its entire color spectrum (blue and green primarily, but also turquoise, pink, yellow, gray, etc.). Moreover, a new assignment A2 was formulated including safety aspects in oil refineries. Students were asked to complete a fault tree analysis on the side stripper of a distillation column, perform a simplified Hazardous Operation Procedure (HAZOP) analysis on a gasoline storage tank, and size a pressure relief valve on a pressure vessel containing an ideal hydrocarbon vapor.

2.2.2 Life cycle analyses discussions in-class

Life cycle analysis (LCA) is a reputed methodological framework often employed to perform a detailed environmental impact and feasibility assessment of a process/product through its five life cycle stages: raw material extraction, manufacturing and processing, transportation, usage and retail, and waste disposal. An LCA analysis typically estimates resource consumption, including energy or carbon emissions. However, despite several efforts toward standardization and universalization, LCAs tend to be specific, as inventory data may often be limited, and they may not necessarily estimate which product/process proves to be most cost-effective or best-performing. Nevertheless, we considered that by resorting to a structured process that analyzed the life cycles of biorefineries, oil refineries, and hydrogen production, LCAs permit for a fair comparative assessment of their individual environmental impact(s) and by extension, their sustainability. For the purposes of course discussion, three existing LCAs from the literature are selected: for oil refining (Liu et al., 2020), biodiesel (Sajid et al., 2016), and hydrogen production (Wilkinson et al., 2023). The instructor provided a summary of these papers during lecture L11, and a comparison table was provided to the students for analysis. Student discussions were to be based around comparing the assumptions and total emissions generated by each of these processes. Current LCAs favor biorefineries/hydrogen-based processes over O&G processes in terms of sustainability, and this is in line with current global energy market trends. However, the road toward a sustainable alternative is not straightforward (expectedly), as standardization efforts are required to accurately evaluate/quantify sustainability through the LCA framework between these options. This exercise aimed to elucidate the inconsistencies between the assumptions employed in the LCAs, and the subsequent challenges in making a fair comparison between different processes.

2.2.3 General discussions

A set of discussion questions was provided to students during the lectures, including: (i) "Can biorefineries be integrated into refineries?", (ii) "How have oil refineries changed over the last 100 years?", (iii) "Are petrochemicals the future of the O&G industry?", (iv) "Do we "need" oilsands?", and (v) "Is hydrogen the fuel of the future?". For each of these prompts, students discussed in depth the advantages and disadvantages of these processes and their corresponding technologies, as well as any foreseeable challenges. These questions were intentionally designed to engage students in current "hot" topics, such as biorefineries and hydrogen production, and topics of controversy, such as petrochemicals/oilsands. We hypothesized that these discussions would promote changes in the students' perception of the O&G industry, which may be inferred from the post-survey results (see section "2.2.4 Assessment of integration effectiveness").

In our general discussions we explored the integration of biorefineries into refineries as an effective path to shift the knowhow from O&G toward clean energy, while simultaneously revamping existent oil refineries. We reviewed the environmental regulations required for upcoming years, and discussed contradictory reports pointing out that these efforts might or not be sufficient to tackle and/or eradicate the concern of the emissions. Other "non-conventional" oil extraction/production processes, such as oil-sands, were also discussed, specifically the potential of oil-sands to produce more pollution than its conventional counterpart, its contribution to Canada's economy, and current innovation efforts to reduce environmental impact.

The discussion about petrochemicals and their role as important raw materials for several processes and final products, was also incorporated in CHE 451. Recycling was the highlight of the discussion, with particular emphasis on the challenges facing current recycling practices worldwide.

Finally, a discussion surrounding blue hydrogen as a feasible alternative to other energy sources, such as coal, petroleum, and natural gas was incorporated. The benefits of blue hydrogen technology, such as the maturity of the production process, as well as the technical challenges around hydrogen storage and transportation were discussed.

2.2.4 Assessment of integration effectiveness

To effectively identify and measure the extent of the impact of the implementation of our sustainability integration strategy in CHE 451, students were asked to anonymously fill out a pre-survey at the beginning and a post-survey at the end of the fall semester. The pre-survey (Rassenfoss, 2019), run through Quercus (the online platform of our university), included three sections. The first section featured two rating-based questions (Q1 and Q2) and was intended to assess the extent of student knowledge on process sustainability in the O&G sector. The second section was related to the perception of the O&G industry and included 15 rating-based questions (Q3 to Q14) and was intended to assess the student's perception of the O&G industry with respect to topics such as innovation, level of pollution, technology, leadership, economic importance, among others. The third section of the pre-survey referred to student's general industry perception, where seven rating-based questions were intended to rank the perception of the following industries: technology, automotive, retail, healthcare, energy, investment banking, and pharmaceutical. The post-survey was designed to assess changes in the students' perception of the course. This was done through three rating-based questions (Q1, Q2, and Q14 from the pre-survey). The rating scale for both surveys was defined from 1 to 5, as shown in **Supplementary Appendices A, B**.

3 Results

Figure 1 shows the results of the pre-survey. In **Figure 1A**, it can be observed that students believe that they are fairly informed about the sustainability approach adopted by the O&G (2.6/5.0). At the same time, students have slightly positive perceptions on how the industry efficiently tackles sustainability issues (3.0/5.0). In **Figure 1B**, we can cluster the responses based on rankings, observing that questions Q3 to Q7 provide the highest-ranking values (greater than 4.0), followed by Q8/Q9/Q11/Q14 (greater than 3.0), and Q10/Q12/Q13 (less than 3.0). The first cluster includes economic variables (e.g., importance to the national economy, it is a major employer, and provides a valuable service) and ranking the industry based on pollution. The second cluster encompasses items regarding how innovative and technologically advanced the industry is and the overall perception of the O&G industry. Finally, the third cluster includes the students' perception of the O&G industry's long-term importance, and the level of trust students have in O&G companies. Based on the results of the pre-survey, we can infer that the students believe the O&G industry plays an important role in the economy (4.6/5.0) and fairly rank its contributions to technological advances and innovations (3.7/5.0); there is an interesting finding that students neither agreed or disagreed that the O&G industry is "not worth the impact to the environment" (2.5/5.0). Finally, the level of trust "to do the right thing" reveals inconclusive results (2.8/5.0).

Figure 1C shows the students' general industry perception (technology, automotive, retail, healthcare, energy, investment banking, and pharmaceutical). Students cautiously rank their positive perception of all industries, with all rankings less than 3.1/5.0. The responses can be clustered into Technology and Energy ("high" positive perception, with 3.1/5.0 average), Pharmaceutical, Healthcare, and Automotive ("medium" positive perception, with 2.3/5.0 average), Retail and Investment Banking ("low" positive perception, with 1.6/5.0 average).

Finally, when comparing the results from the pre- and post-surveys (Q1, Q2, and Q14), **Figure 2** reveals that students perceive that they are better informed about the sustainability approach adopted by the O&G industry at the end of the semester (+54.8%

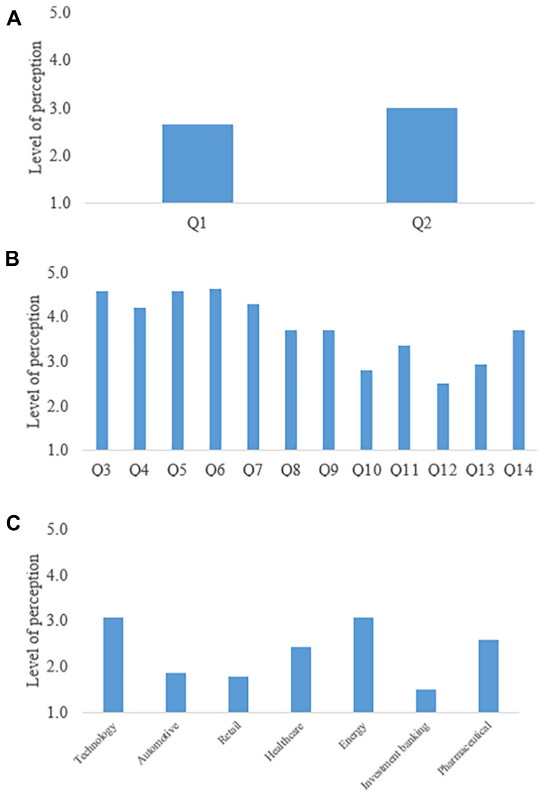

FIGURE 1
Pre-survey results: **(A)** questions 1 and 2, **(B)** questions 3 to 14, and **(C)** general industry perception.

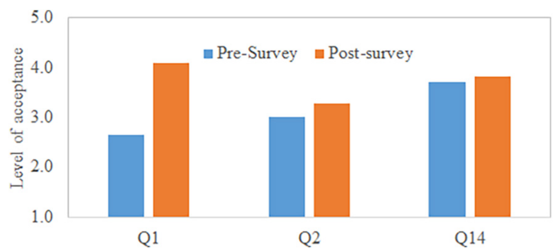

FIGURE 2
Comparison of University of Toronto students' perception before and after the course.

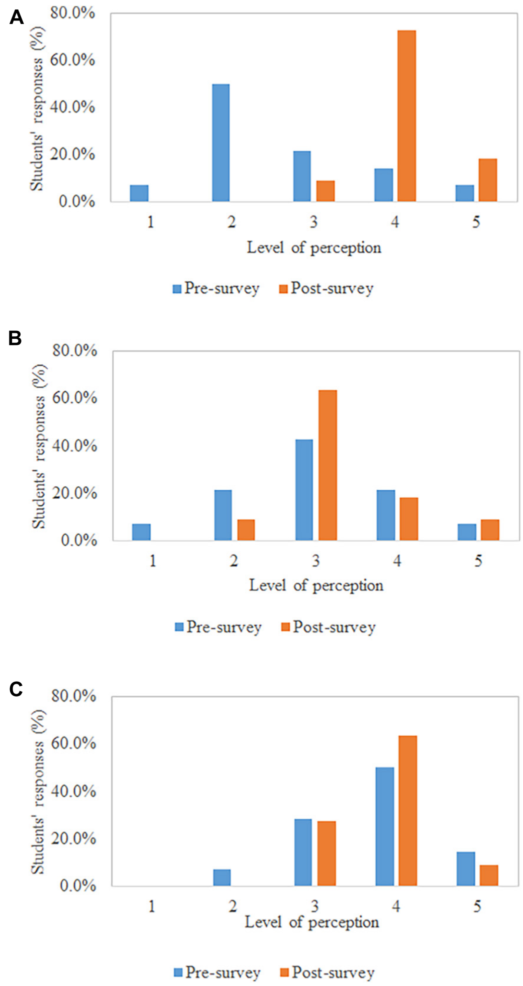

FIGURE 3
Distribution of responses in the pre- and post-surveys, **(A)** Q1, **(B)** Q2, and **(C)** Q14.

compared to the pre-survey). A +9.1% for Q2 reveals that students have a "more positive" perception of the O&G industry efficiently tackling sustainability issues; nevertheless, there is no substantial increase in terms of their "positive" overall perception of the industry (+2.8% for Q14). We believe that by revamping the course Petroleum Processing, students became more informed about the current trends and challenges related to the O&G industry and the energy transition, as was reflected in the post-survey results.

Figure 3A shows the distribution of responses in the pre- and post- surveys for the students. For Q1, a larger variation in student responses can be seen in the pre-survey in comparison to the post-survey. In the pre-survey, student responses for all five level of perception ratings were reported, with 50.0% of the students submitting a response of 2 ("disagree"). In comparison, in the post-survey, only three different levels of perception ratings were reported, with 72.7% of the students submitting a response of 4 ("agree"). From this result we can infer that students entered the class with different levels of perceived knowledge surrounding sustainability approaches in O&G and that by the conclusion of the course, the majority of students reported.

Figure 3B shows that prior to the course delivery, the students' rankings for Q2 followed a "normal-like" distribution. Following course delivery, there is a shift in this distribution, with 63.6% of students reporting a ranking of 3 ("neither agree or disagree") and no students reporting a ranking of 1 ("strongly disagree").

Figure 3C shows minimal change in the distribution pattern of survey responses for Q14, however there was an increase of 13.6% in the number of students that reported a ranking of 4 ("agree").

In order to investigate the generalizability of the pre-survey findings, future work will include conducting similar surveys across different higher education institutions in different locations. For example, within Canada, students' responses in provinces such as Alberta may differ, as in this province, O&G is a larger contributor to its GDP, compared to the province of Ontario. Post-surveys can also be conducted in different institutions (including different

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countries), considering different levels of sustainability content, to understand the impact that it has on students' perceptions. For instance, it would be quite interesting to compare students' perceptions in countries where the O&G industry makes a large contribution to the country's GDP in comparison to Canada (The World Bank, 2021). Most notably, our approach paves the pathway for a more rigorous curriculum design/development. The role of sustainability to create more inclusive, well-aware students has been documented in the construction sector (Hayles and Holdsworth, 2008), and that the predominant aim of environmental education is to change perceptions, bias, attitudes, to impact collective behavior change (Cotgrave and Kokkarinen, 2010). The biggest barriers to the incorporation of sustainability in an existent curriculum are, perhaps, academic indifference and approach toward teaching and assessment, student backgrounds, and lack of effective communication between the industry and academia (Cotgrave and Kokkarinen, 2010). This work provides a "middle-path" that does not shame the existent O&G sector, but instead, consciously presents sustainability in this sector in an unbiased fashion to university students, empowering them to critically assess and take their unique stance and perceptions on this industry.

Our results might have significant implications in the context of curriculum design and sustainability issues, which becomes even more relevant for future "environmentally conscious" generations. It is worthwhile to comprehensively understand the drivers and barriers for/toward curriculum change, to identify and develop a compatible framework to realize these goals. The instructor's ability, as well as the techniques/modes of delivery of the lecture content is also known to influence student perceptions (Stubbs and Schapper, 2011). What is also most reassuring is the fact that our approach has been shown to work in other scenarios, such as the comparative study between the UK and Australia, to develop appropriate curriculum design and promote sustainable literacy in construction education (Cotgrave and Kokkarinen, 2010). Likewise, attempts in the USA (Vincent and Focht, 2011) to obtain an ideal view of student curriculum reveal three curricular models (Systems Science, Policy and Governance, and Adaptive Management) as being most favored. A review on the characteristics of a sustainable curriculum (Woo et al., 2012) reveal that the key characteristics of curriculum structure should be based on complexity of knowledge (being flexible and permeate at a given discipline level), contextualization, prospective orientation, as well having consistency between theoretical concepts and practical cases. Simultaneously, teaching methods for instructors are more valued if they incorporate authentic learning experiences, reflection/introspection space, mutual learning, and research. Our approach to revamp a university elective curriculum builds on these "best practices" and is likely to pave the way for more pedagogical revamps across several universities in the future. As learning competencies become more technology-based (Chakraborty et al., 2023), it becomes progressively critical to integrate sustainability initiatives toward a more Artificial Intelligence (AI) predominated world; both contributing extensively toward the E.D. 4.0 goal and the I.D. 4.0 competencies. There is a growing revolution of Higher Education Institutions (HEI) to integrate curricula with the UN's Sustainable Development Goals (Cuevas-Cancino et al., 2024), and our work serves to clearly demonstrate how such pedagogical initiatives may be integrated/revamped into existing university curricula.

4 Conclusion

In this work, an undergraduate course in Petroleum Processing was revamped to include sustainability-related content, as well as the facilitation of open discussions to debate the pros and cons of sustainability approaches adopted by O&G industry. A pre-survey gathered information regarding the students' perception of the O&G industry, O&G industry with respect to other industries, as well as how well-informed students believe they are on the sustainability measures currently employed by the O&G industry. A post-survey was administered following completion of the course to assess changes in students' perceptions related to the pre-survey. We believe that the changes implemented in the course Petroleum Processing make students more informed about the current challenges facing the O&G industry regarding sustainability and trends in approaches taken to contribute to the energy transition by consciously presenting sustainability in this sector in an unbiased fashion to university students, to ultimately empowering them to critically assess and take their unique stance and perceptions on this industry. Moreover, our results might have significant implications in the context of curriculum design integrating sustainability issues for future "environmentally conscious" generations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the University of Toronto, Ethics Protocol 44048. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC: Formal analysis, Investigation, Validation, Writing – original draft. SK: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft. YG: Conceptualization, Formal analysis, Investigation, Resources, Writing – review & editing. JM: Formal analysis, Investigation, Resources, Visualization, Writing – review & editing. DG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1396377/full#supplementary-material

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