

Exploratory Study of Sustainability Courses in Collegiate Level Engineering Programs

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INTRODUCTION

The aerospace and aviation industries have committed to becoming more sustainable. The challenge is to continue carbon neutral growth past 2020 and to reduce CO_{2e} by 50% by 2050, based on 2005 levels [1]. This challenge has been affirmed through agreements in industry organizations such as IATA, A4A, ATAG, CAAFI, and many other similar organizations around the globe [2][3]. Aerospace companies recognize improving aircraft technology as one way to contribute their knowledge, skills, and abilities to achieving the global industry goal of reaching the 50% reduction by 2050. To achieve these dramatic reductions, it will take global industry-wide efforts concentrating on aircraft technology, operational improvements, sustainable fuels, and market-based measures [1]. There is a need to develop courses that address these issues to prepare students for challenges that have the potential to dominate the leading edge of research and implementation for the next 25 or more years.

In this paper, the researchers aim to explore inclusion of sustainability courses offered in United States engineering degree programs with reports submitted to the Association for the Advancement of Sustainability in Higher Education (AASHE) and have received platinum ratings. The goal is to identify courses that are focused on or inclusive of sustainability at undergraduate and graduate level in engineering programs. Through the analysis, researchers aim to provide insights about patterns in sustainability education across highly rated universities in sustainability. The study may be used as a starting point to compare sustainability education in aerospace engineering with other engineering programs which may be helpful for educators, business professionals, and students in identifying programs where sustainability is important. In addition, the study may reflect those education areas where sustainability is not included and there is an opportunity to develop related courses.

BACKGROUND

The United Nations (UN) has established 17 sustainable development goals (SDGs) as a way of implementing sustainable development [4]. The Brundtland Commission [5] defined sustainable development as:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of “needs”, in particular the essential needs of the world’s poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs” [5].

Sustainability sometimes is equated with environmental impacts. One may see from the definition of sustainable development offered by the UN that social organization and technology are also included. Sustainability extends beyond TBL or PPP (triple bottom line or people, profit, planet) coined by Elkington [6], and turns to an action-oriented strategy when viewed in terms of the 17 SDGs [7]. The United Nations noted in their 2030 agenda that people, planet, prosperity, peace and partnership are important aspects of sustainable development [8].

Universities must conduct research and education while themselves becoming potentially more sustainable. The Global Reporting Initiative (GRI) standards [9] provide a structure for sustainability and some sector-specific guidance that focus on economic, environmental, and social sustainability. Universities may or may not choose a GRI standard approach. The Association for the Advancement of Sustainability in Higher Education (AASHE) is an organization that is specifically addressing the needs of education and research entities when implementing sustainability on campuses in terms of their operations, facilities, education, outreach, and research, among others [10].

AASHE STARS[®] and STARS[®] Ratings: AASHE’s STARS[®] (Sustainable Tracking, Assessment, and Reporting System) is a tool to facilitate the implementation of sustainability. There are 1,078 institutions that have registered to use the STARS[®] Reporting Tool, of which 680 have earned a STARS[®] rating [11]. Each institution is evaluated across Academics, Engagement, Operations, and Planning & Administration to receive an Overall STARS[®] Score. STARS[®] ratings range from Platinum, Gold, Silver, Bronze, and Reporter [10]. The calculation of the STARS[®] score is developed by the university and supported through documentation [12]. Table 1 shows the AASHE STARS[®] ratings, minimum Overall Score for each rating, and the number of institutions with each type of ratings.

Table 1. AASHE STARS[®] Ratings [12] [13] as found in February 2022.

AASHE STARS [®] Ratings	Minimum Overall AASHE STARS [®] Score	Number of Institutions with valid STARS [®] reports
Platinum	85	10
Gold	65	136
Silver	45	159
Bronze	25	42
Reporter	n/a	17

METHODOLOGY

This section details the data sources, collection, and analysis procedures followed in this paper.

Data Sources and Collection: The data for this paper was collected from the sustainability reports submitted by higher education institutions to AASHE and were available through the AASHE website in February 2022. In this paper, sustainability reports and scores of institutions located in United States that have received a platinum STARS[®] rating were selected. Table 2 presents the list of the selected nine universities. For each institution, their latest STARS[®]

Version reports were analyzed. If multiple reports were available for these universities, the latest, unexpired version of AASHE report was considered for analysis.

The STARS[®] program of AASHE is a transparent, self-reporting framework for institutions to measure their sustainability performance [13]. Each institution is evaluated across Academics, Engagement, Operations, and Planning & Administration to receive an Overall STARS[®] Score [13]. Since the goal of this research is to identify sustainability inclusive/focused courses in engineering programs, the data collection was focused on the Academics section of the reports.

The Academics section is divided into Curriculum and Research. The Curriculum section carries 40.00 points toward the Overall STARS[®] Score, while the Research section carries 18.00 points. Within the Curriculum section, Academic Courses contribute 14.00 points. Table 2 lists the Overall STARS[®] Scores, Curriculum Points, and Academic Courses Points for each of the institutions selected in this study.

Table 2. United States institutions with Platinum STARS[®] rating (as of February 2022)

Institution	Location	Rating and Valid through	Overall AASHE STARS [®] Score	Curriculum Points (Out of 40.00)	Academic Courses Points (Out of 14.00)
Colorado State University [14]	United States, CO	Platinum Dec. 5, 2022	88.14	40.00	14.00
Stanford University [15]	United States, CA	Platinum Feb. 21, 2022	88.00	38.20	12.20
Arizona State University [16]	United States, AZ	Platinum March 5, 2023	87.10	37.31	11.98
Cornell University [17]	United States, NY	Platinum May 6, 2024	85.12	37.81	12.44
State University of New York College of Environmental Science and Forestry [18]	United States, NY	Platinum April 29, 2024	85.66	40.00	14.00
University of California, Berkeley [19]	United States, CA	Platinum April 29, 2024	85.39	36.31	13.94
University of California, Irvine [20]	United States, CA	Platinum Oct. 14, 2024	88.59	38.00	14.00
University of New Hampshire [21]	United States, NH	Platinum Oct. 21, 2024	86.09	39.52	13.52
University of Connecticut [22]	United States, CT	Platinum March 6, 2023	86.01	39.14	13.14

Sustainability courses inventory list: Within the Academic Courses in Curriculum, each institution reports the total number of courses offered by the institution, number of sustainability courses offered, and number of courses offered that include sustainability. In addition, each institution submits reports of the institution's inventory of its sustainability course offering and their descriptions. The institutions self-report their sustainability focused and sustainability inclusive courses in these reports. For this study, these inventory reports are analyzed to identify the sustainability courses specific to the institution's engineering programs. For that reason, academic departments that have "Engineering" word in their names or are under respective engineering schools were identified through the institutions home website or through department names on the sustainability courses inventory reports.

For each of the nine selected institutions, engineering programs and departments were listed. Then, the inventory lists were searched according to the department codes/contractions and courses. For each engineering program/department of each institution, sustainability inclusive and sustainability focused courses at undergraduate and graduate levels were identified and counted. Note – some institutions provide a complete list of their courses instead of sustainability specific courses, and then categorize their courses as focused, inclusive, or not applicable (n/a). In this paper, only the courses explicitly self-identified and self-reported as sustainability focused or inclusive, are considered for analysis. Engineering courses in the inventory list with a n/a identification are not counted.

Grouping engineering programs: Once the sustainability focused and inclusive courses at undergraduate and graduate level in various engineering programs of each institution were identified and counted, the similar engineering programs were grouped into one category. Different institutions may have different names for similar type of programs. For example, Civil Engineering, Civil and Environmental Engineering, and Construction Management and Environmental Engineering were grouped as *Civil and Environmental Engineering and similar*. Similarly, Mechanical Engineering, Aerospace and Mechanical Engineering, and Aerospace and Aeronautics Engineering were grouped as *Mechanical and Aerospace Engineering and similar*. The counts of sustainability focused and inclusive courses at undergraduate and graduate levels were added for the programs in each group.

RESULTS

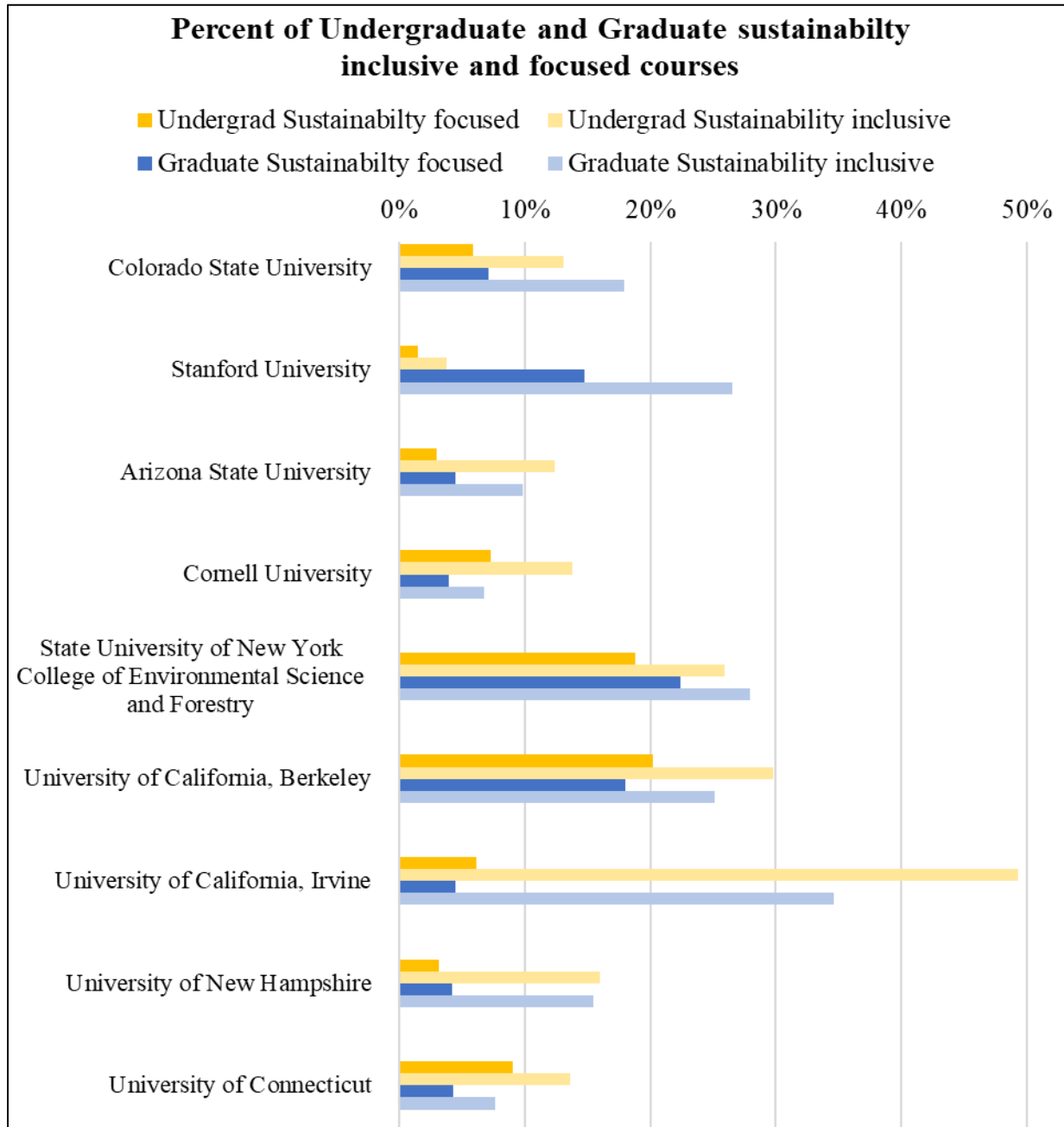
This section details the results of this paper.

Overall number of courses: For each institution in the study, the total number of courses, number of sustainability focused courses, and number of sustainability inclusive courses at undergraduate and graduate level are presented in Table 3. Figure 1 shows a comparison of the percent of undergraduate and graduate sustainability inclusive and focused courses offered by each institution. Almost 50% of the undergraduate courses and 35% of graduate courses at University of California, Irvine, are inclusive of sustainability. Each of the other universities have less than 30% of courses inclusive of sustainability. The State University of New York College of Environmental Science and Forestry and the University of California, Berkeley, are the leading institutions in the number of sustainability focused courses offered.

Table 3. Total number of sustainability courses offered by institutions.

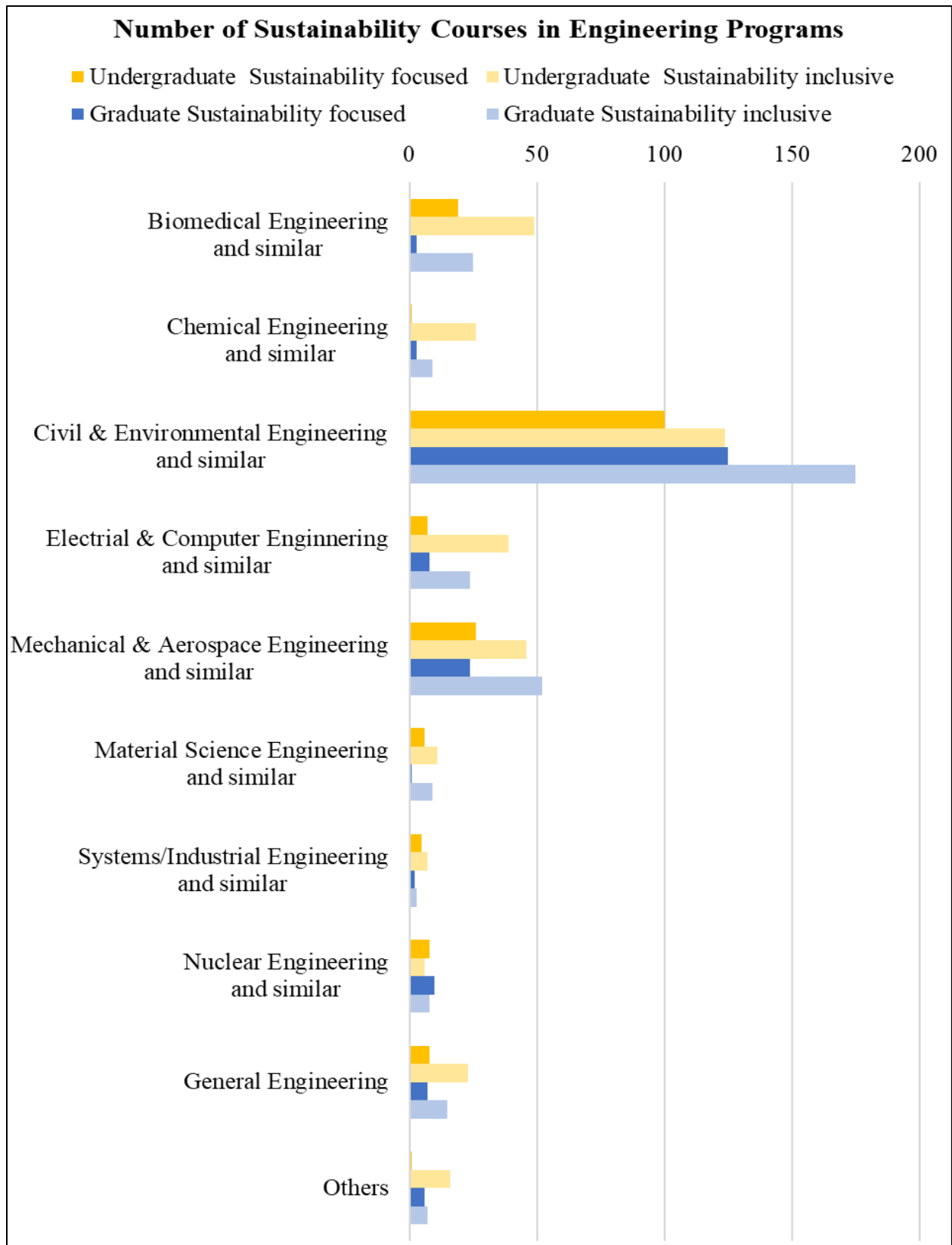
Institution	Total number of courses offered by the institution		Number of sustainability focused courses offered		Number of sustainability inclusive courses offered	
	Undergrad	Graduate	Undergrad	Graduate	Undergrad	Graduate
Colorado State University [14]	1840	1038	108	74	241	186
Stanford University [15]	3792	2275	57	336	142	603
Arizona State University [16]	4121	2468	122	111	509	243
Cornell University [17]	2509	2300	183	90	345	156
State University of New York College of Environmental Science and Forestry [18]	467	344	88	77	121	96
University of California, Berkeley [19]	3864	2990	781	538	1151	751
University of California, Irvine [20]	1628	1104	100	49	802	382
University of New Hampshire [21]	2190	713	70	30	350	110
University of Connecticut [22]	2878	2334	260	101	391	178

Figure 1. Percent of sustainability inclusive and focused courses across Platinum rated universities.



Sustainability Courses in Engineering Programs: The number of sustainability inclusive and focused courses in undergraduate and graduate engineering programs are shown in Figure 2. The engineering programs are grouped based on similarities. For example, Mechanical Engineering, Aerospace and Mechanical Engineering, and Aerospace and Aeronautics Engineering are grouped as *Mechanical and Aerospace Engineering and similar*. Figure 2 shows the combined total number of sustainability focused and inclusive courses in the engineering programs of the nine selected institutions.

Figure 2. Number of sustainability courses by engineering programs.



Clearly from Figure 2, Civil and Environmental engineering programs offer the most number of sustainability inclusive and focused courses. More than 250 sustainability inclusive courses are offered in the civil and environmental engineering programs across the platinum rated institutions. More than 200 sustainability focused courses are offered in this program across the nine institutions. Mechanical and Aerospace engineering programs rank second in terms of the number of sustainability focused courses offered. However, there are less than 50 sustainability focused courses offered in the mechanical and aerospace engineering programs across the platinum rated universities.

DISCUSSION

Sustainability is an encompassing area of study that defies most attempts at simplifying it into a slogan. Due to the allocation of precious resources at universities, the counting of courses and comparisons reveal indications of the importance of sustainability in engineering programs. In this study, the engineering programs at universities with a platinum AASHE rating were explored. Civil engineering may be a logical place to incorporate sustainability in academic programs due to the focus on systems affecting where and how people live. Not surprisingly, civil engineering and environmental engineering programs have the greatest numbers of courses focused on or inclusive of sustainability in this study.

In the platinum rated universities selected for this study, it was noted that the number of sustainability focused or inclusive courses offered in mechanical and aerospace engineering programs were much lower than in civil and environmental engineering programs, and almost at the same level as biomedical engineering programs. This finding may indicate a need to increase sustainability education in aerospace engineering. As noted by ICAO that recommends aviation practices world-wide, global carbon reduction goals are believed to be able to be achieved by combined efforts in technological development, operational and infrastructure improvements, sustainable fuels, and market-based measures [1]. Most of these developments and improvements require engineers to develop and implement technologies, improvements, and fuels. With the aspirational goal of reducing carbon dioxide equivalent emissions by 50% while growing the amount of cargo and passengers transported, aerospace engineers and many other types of engineers will be needed that know how to identify and measure sustainability risks and innovate sustainable solutions. Future aerospace engineers may be key to achieving the sustainability goals set by ICAO, by airlines represented by groups such as A4A [23], or by aircraft companies such as Airbus with the goal of developing the first zero-emission commercial service aircraft by 2035 [24]. Airbus identifies partnerships across the globe as it works toward the 2050 goal [24]. Prediction of a “seismic shift” in aerospace [24] requires engineers prepared to make these changes; courses that include sustainability exist but could be expanded in aerospace engineering.

It is important to note that this paper explores the platinum rated US universities listed on AASHE. This rating is based on an overall score achieved by evaluating universities across Academics, Engagement, Operations, and Planning & Administration. The rating is not solely based on the number of sustainability inclusive and focused courses in these universities.

Therefore, it is possible that gold, silver, bronze, reporting rated or non-participating universities may be offering more sustainability courses in engineering programs. Moreover, the extent of this paper is only to identify and report the number of sustainability inclusive and focused courses, and not analyze the courses. Some course titles and descriptions are available on AASHE, but a more detailed comparison of courses is needed to compare the content and effectiveness of the sustainability focused and inclusive courses.

The results of this paper may be useful for students to identify engineering programs and universities that offer sustainability focused courses. For educators in aerospace engineering programs, the results of this paper may encourage them to further explore how their courses may incorporate technologies that support international sustainability goals for aviation.

CONCLUSION

In this paper, the researchers explored the inclusion of sustainability courses offered in United States engineering degree programs at universities with platinum ratings reported to the Association for the Advancement of Sustainability in Higher Education (AASHE). Through the analysis of the numbers of courses offered by these universities, researchers sought to reveal patterns in sustainability education in these engineering programs. Certainly, the number of courses offered may be used to compare sustainability education in engineering programs. However, the authors caution that number of courses is an indicator; it is not the sole or defining indicator of delivery of sustainability education to graduate and undergraduate students. Future research might seek to develop comparative case studies of course learning outcomes and develop a deeper understanding of how these learning outcomes are assessed. Participating in a ratings program may be helpful for educators, business professionals, and students in identifying programs where sustainability is important. By examining those education areas where sustainability is not included, there is an opportunity to develop related courses and programs that meet the needs of society.

REFERENCES

- [1] International Civil Aviation Organization (ICAO), “Resolution A40-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Climate change,” Environmental Protection Documents, ICAO, 2019. Retrieved March 27, 2022, from https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A40-18_Climate_Change.pdf
- [2] Airlines for America (A4A), “A4A’s Climate Change Commitment,” A4A, 2022. Retrieved March 27, 2022, from <https://www.airlines.org/a4as-climate-change-commitment/>
- [3] Air Transport Action Group (ATAG), “Climate Change,” ATAG, 2022. Retrieved March 27, 2022, from <https://www.atag.org/our-activities/climate-change.html>
- [4] United Nations, “THE 17 GOALS | Sustainable Development,” n.d. Retrieved March 27, 2022, from <https://sdgs.un.org/goals>
- [5] World Commission on Environment and Development, “Our Common Future, Chapter 2: Towards Sustainable Development,” UN Documents: Gathering a Body of Global Agreements, United Nations, 1987. <http://www.un-documents.net/ocf-02.htm>
- [6] J. Elkington, “Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development,” *California Management Review*, 36(2), 90–100, 1994. <https://doi.org/10.2307/41165746>
- [7] J. Elkington, “25 years ago I coined the phrase ‘triple bottom line.’ here's why it's time to rethink it.,” *Harvard Business Review*, 13-Sep-2018. [Online]. Available: <https://hbr.org/2018/06/25-years-ago-i-coined-the-phrase-triple-bottom-line-heres-why-im-giving-up-on-it>. [Accessed: 21-Feb-2022].
- [8] United Nations (UN), “Transforming our world: The 2030 agenda for sustainable development,” A/RES/70/1, 2015. Retrieved January 10, 2021, from https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E
- [9] Global Reporting Initiative, “GRI – Standards,” GRI, 2022. Retrieved February 21, 2022, from <https://www.globalreporting.org/standards/>
- [10] Association for the Advancement of Sustainability in Higher Education, “About STARS The Sustainability Tracking, Assessment & Rating System,” AASHE, November 8, 2018. <https://stars.aashe.org/about-stars/>
- [11] Association for the Advancement of Sustainability in Higher Education, “Participants & Reports | Institutions | STARS Reports,” AASHE, 2019. <https://reports.aashe.org/institutions/participants-and-reports/?sort=rating>
- [12] Association for the Advancement of Sustainability in Higher Education, “Participate STARS,” AASHE, February 3, 2021. <https://stars.aashe.org/participate/>
- [13] Association for the Advancement of Sustainability in Higher Education, “STARS, Sustainability Tracking Assessment & Rating System,” AASHE, STARS, November 15, 2021. <https://stars.aashe.org/>

- [14] Association for the Advancement of Sustainability in Higher Education (AASHE), “Academic Courses | Colorado State University | Scorecard | Institutions | STARS Reports,” AASHE, STARS, December 6, 2019. <https://reports.aashe.org/institutions/colorado-state-university-co/report/2019-12-06/AC/curriculum/AC-1/>
- [15] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | Stanford University | Scorecard | Institutions | STARS Reports,” AASHE, February 22, 2019. <https://reports.aashe.org/institutions/stanford-university-ca/report/2019-02-22/AC/curriculum/AC-1/>
- [16] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | Arizona State University | Scorecard | Institutions | STARS Reports,” AASHE, March 5, 2020. <https://reports.aashe.org/institutions/arizona-state-university-az/report/2020-03-05/AC/curriculum/AC-1/>
- [17] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | Cornell University | Scorecard | Institutions | STARS Reports,” AASHE, March 4, 2021. <https://reports.aashe.org/institutions/cornell-university-ny/report/2021-03-04/AC/curriculum/AC-1/>
- [18] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | State University of New York College of Environmental Science and Forestry | Scorecard | Institutions | STARS Reports,” AASHE, March 5, 2021. <https://reports.aashe.org/institutions/state-university-of-new-york-college-of-environmental-science-and-forestry-ny/report/2021-03-05/AC/curriculum/AC-1/>
- [19] Association for the Advancement of Sustainability in Higher Education. “Academic Courses | University of California, Berkeley | Scorecard | Institutions | STARS Reports,” AASHE, March 4, 2021. <https://reports.aashe.org/institutions/university-of-california-berkeley-ca/report/2021-03-04/AC/curriculum/AC-1/>
- [20] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | University of California, Irvine | Scorecard | Institutions | STARS Reports,” AASHE, August 11, 2021. <https://reports.aashe.org/institutions/university-of-california-irvine-ca/report/2021-08-11/AC/curriculum/AC-1/>
- [21] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | University of New Hampshire | Scorecard | Institutions | STARS Reports,” AASHE, August 16, 2021. <https://reports.aashe.org/institutions/university-of-new-hampshire-nh/report/2021-08-16/AC/curriculum/AC-1/>
- [22] Association for the Advancement of Sustainability in Higher Education, “Academic Courses | University of Connecticut | Scorecard | Institutions | STARS Reports,” AASHE, March 6, 2020. <https://reports.aashe.org/institutions/university-of-connecticut-ct/report/2020-03-06/AC/curriculum/AC-1/>
- [23] Airlines for America (A4A), “A4A’s Climate Change Commitment”, A4A, March 28, 2022. <https://www.airlines.org/a4as-climate-change-commitment/>
- [24] Airbus, “Decarbonization: towards more sustainable aerospace for future generation”, Airbus, March 28, 2022. <https://www.airbus.com/en/sustainability/environment/climate-change/decarbonisation>