Integrating Sustainability in Higher Education: Curricular Review and Opportunities for Future Development

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Abstract

Rose-Hulman Institute of Technology (RHIT) is renowned for its commitment to providing the finest undergraduate education in science, engineering, and mathematics. With a mission dedicated to support students in an individualized learning experience, RHIT strives to be a global leader of engineering and science education. In line with its vision, the institution aims to produce graduates who are not only inspired and prepared for success but also equipped to address the complex challenges facing our global society. We have comprehensively explored RHIT's sustainability education, examining its initiatives, curriculum, and integration of sustainability principles across various disciplines. By delving into the sustainable practices and educational approaches employed by the institute, we can better understand how RHIT is cultivating a generation of engineers and scientists who possess the knowledge and skills needed to define and solve the multifaceted problems of our complex global society. This report does not look to guide RHIT in its campus sustainability indicated through resource consumption, waste management, or sustainability reports. However, sustainability education extends beyond what is present strictly in the curriculum through various co-curricular and extracurricular activities which may incite discussion of the sustainability culture present at RHIT as indicated by any campus sustainability commitments. By analyzing the current state of sustainability education at RHIT and its relevance in meeting the institution's strategic goals, we can pave the way for a brighter and more sustainable future. Upon review of the school’s course catalog, courses were categorized as fitting into four tiers related to the level of sustainability coverage and the potential for incorporating sustainability content. Survey data was collected from current students and faculty to assess perceptions of sustainability coverage in courses. Finally, we reviewed sustainability-related degree programs and course offerings at peer institutions to assess how these institutions were addressing sustainability in education. Having examined the baseline of sustainability education at RHIT and reviewed the availability of sustainability education at other peer institutions, this assessment provides an initial understanding of the current opportunities at RHIT. To complement the value of this baseline assessment, common practices and comprehensive guides of integration of sustainability pillars and the United Nation’s Sustainable Development Goals in education are summarized to recognize other areas of potential. By acknowledging the existing efforts and identifying areas for improvement, further advancements in sustainability education are proposed that align with the local institutional strategic planning goals to enhance sustainability education at RHIT and can guide other institutions of higher education in their endeavors. Collective efforts and a commitment to continuous improvement can enable similar institutions to instill mindsets of sustainability in students to address sustainability-related global challenges utilizing RHIT as a case study.

Introduction

To fulfill its vision, Rose-Hulman Institute of Technology (RHIT) recognizes the importance of improving and developing in emerging areas of study to maintain the school’s vision as leaders in undergraduate education. As the institute prepares to embark on its newly adopted strategic

plan, which features sustainability as one of four principal areas of institutional enhancement, it is vital to understand the current state of RHIT's sustainability education. Such an evaluation will shed light on the institution's progress, strengths, and areas for improvement in meeting its overarching mission and vision with respect to sustainability education.

This report aims to comprehensively explore RHIT's sustainability education, examining its initiatives, curriculum, and integration of sustainability principles across various disciplines. By delving into the sustainable practices and educational approaches employed by the institute, we can better understand how RHIT is cultivating a generation of engineers and scientists who possess the knowledge and skills needed to define and solve the multifaceted problems of our complex global society.

Following the assessment of the institute’s approaches to sustainability education, additional insights are offered for translating sustainability goals into learning outcomes, engineering curricula, and tools for measuring student and faculty success.

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As noted in RHIT's new strategic plan, *Advancing by Design*, a theme to integrate sustainability in education and the campus culture emerged and strategic actions are being developed to implement a plan that meets this goal. This paper seeks to contribute to the ongoing development of RHIT's sustainability efforts, offering insights and recommendations that align with the institute's mission, vision, and aspirations for the future.

By analyzing the current state of sustainability education at RHIT and its relevance in meeting the institution's strategic goals, we can pave the way for a brighter and more sustainable future. This comprehensive assessment aims to support RHIT in its journey towards becoming a recognized global leader in science, engineering, and mathematics education, empowering its graduates to create meaningful impact and contribute to the resolution of global challenges.

Defining Sustainability

Ensuring a precise and well-defined understanding of sustainability is of paramount importance in this study. The term "sustainability" is one that permeates various fields of study, ranging from environmental science to business development. Its versatility and multiple applications across disciplines necessitate a clear and explicit definition to avoid ambiguity and ensure consistency in our analysis. With this recognition, a definition of sustainability was crafted from definitions available from the widely recognized 1987 United Nations Bruntland Commission definition of sustainability [1] and University of California Los Angeles’s definition of sustainability present within its publicly available University Sustainability Committee charter [2].

1. United Nations Brundtland Commission recognizes sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [1].

2. University of California Los Angeles recognizes sustainability as “the integration of environmental health, social equity, and economic vitality to create thriving, healthy, diverse, and resilient communities for this generation and generations to come. The practice of sustainability recognizes how these issues are interconnected and requires a systems approach and an acknowledgement of complexity” [2].

3. The crafted definition of sustainability utilized for the sake of this report recognizes sustainability in multiple segments (development and practices) to allow for easier connections between engineering principles and sustainability:
   Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Practicing sustainable development requires an acknowledgement of how these issues are complexly interconnected. Sustainable practices support ecological, human, and economic health and vitality. Sustainability presumes that resources are finite and should be used conservatively and wisely with a view to long-term priorities and consequences of the ways in which resources are used. This covers levels of individual, local, organizational, and national/international impacts [1],[2].

This third definition will serve as the lens through which we interpret the perspectives of students and faculty members. By employing this consistent definition throughout the surveys and interviews conducted at RHIT, we aim to gain insights into how sustainability is perceived, understood, and integrated into various academic disciplines. The use of a standardized definition ensures that the data collected from these surveys and interviews can be effectively analyzed and compared, enabling us to identify patterns, challenges, and opportunities related to sustainability education within the institution.

Classifications of Sustainability-related Courses

To classify whether courses align with the previously stated definition, a tiering system was utilized to divide courses into comprehensible categories of how a course includes sustainability or could include sustainability within its curriculum.

The tiering system comprises four levels: "A-Tier," "B-Tier," "C-Tier," and "D-Tier." Each tier is accompanied by a specific definition that serves as a guideline for classifying courses accordingly:

A-Tier courses are highly centralized or encompass concepts of sustainability. They are courses built around the foundation (or a foundation) of sustainability and how it applies to the engineering, technical, or sociocultural topic discussed in the course.

B-Tier courses have a primary focus on some engineering, technical, or sociocultural topics that can be or are conjoined with a segment related to sustainability. The topic at hand, while not inherently focused around sustainability, can include a conversation relating that topic to sustainability to enhance the quality of education received for that topic.

C-Tier courses have a primary focus on some engineering, technical, or sociocultural topic with a major component of the course being a project through which sustainability could be applied. The course itself includes enough flexibility that a professor or students with significant interest in sustainability can delve into projects or assignments related to sustainability should they choose.

D-Tier courses are general courses which many students encounter or courses which use data from real examples from implements of sustainability. These are courses that could provide a context of sustainability to increase the exposure that students have to some aspect of sustainability – hopefully encouraging some students to further pursue sustainability education. The loose definition of this tier is supportive of any course, so note the listed courses are courses identified by students or faculty as courses of potential.

As an initial baseline, the course definitions publicly available in RHIT's 2022-2023 course catalog allowed for placement of courses within the different tiers. This initial baseline was then brought to multiple department heads and faculty for feedback to allow for adjustments based on information not present in the publicly available course definitions. While all department heads and additional faculty were contacted, not all were able to provide feedback within the timeframe of this assessment.

A-Tier Courses:

- Introduction to Environmental Science
- Sustainable Civil Engineering Design
- Energy and the Environment
- Green Chemistry
- Sustainable Energy Systems
- Environmental Economics
- Introduction to Sustainability
- Global Engineering and Social Context
- Sustainability in Practice
- Seminar in Sustainability
- Renewable Energy

B-Tier Courses:

- Evolution and Diversity
- Ecology
- Evolutionary Biology
- Water Resources Engineering
- Environmental Engineering
- Civil Engineering Codes and Regulations

- Safety, Health, and Loss Prevention
- Principles of Design
- Power and Energy Systems
- Supply Chain Management
- Systems Engineering
- Creative Design
- Disasters and Modern Society
- Cities and Technology in the Industrial Age
- Bioethics
- Business & Engineering Ethics
- Nature & Religion

C-Tier Courses:

- Introduction to Design
- Senior Capstone Design
- Material Science and Engineering
- Design for Manufacturing
- Technical Communication
- Software Project Management
- Six Sigma
- Computing in a Global Society
- Computational Modeling
- Product Design

D-Tier Courses:

- Engineering Statistics
- Biomaterials
- Entrepreneurship and Leadership
- Polymer Engineering
- Nanomaterials
- Organic Chemistry
- Data Structures and Algorithm Analysis
- Systems Biology
- Object-oriented Programming

Considering a future discussion on enhancing sustainability education, general goals of incentivizing a more refined depth of sustainability topics within these tiered courses can strengthen the breadth of sustainability education at RHIT.

General outcomes of the tiered courses with respect to the definitions of each tier may include:

1. An inclusion of some aspect of sustainability through assignment or project revision within the D-Tier courses to increase familiarity of students with topics of sustainability without negatively impacting the primary educational focus of the course.

2. A refinement of projects or some course material at it relates to the educational focus of C-Tier courses to encourage that the educational focus of that course can be associated with principles of sustainability for students who hold such interests.

3. Incorporating a segment of sustainability or refining a project within sustainability as it relates to the educational focus of B-Tier courses to bring engagement of students with principles of sustainability as it relates to the educational focus of that course.
    a. B-Tier courses are less likely to highly focus on sustainability to the extent of an A-Tier course as the B-Tier course's goals would need to center around sustainability instead of its original educational focus.

4. Increasing the breadth of available A-Tier courses to set more students in a relevant direction more in line with sustainability opportunities within science, engineering, and mathematics.

It is important to note that the tiering of RHIT courses presented above serves as a guide rather than a final or officially recognized assessment of sustainability education within the institution's curriculum. The feedback received helped refine the placement of courses and incorporate additional information not readily available in the course catalog definitions. However, further revisions and updates may be necessary as the understanding and interpretation of sustainability in education continues to evolve.

Useful Insights from Survey Data

In efforts to better understand the placement of RHIT's sustainability education, a survey was designed. The survey had differing questions for whether the interviewee was a student or a faculty member to gain insights into these different perspectives. The definition of sustainability defined above was provided to the interviewees and they were asked:

Student Survey:
1. In what year of study are you?
2. What is your anticipated major degree? Any anticipated minor degrees?
3. What courses have you taken that discussed themes of sustainability?
4. What projects/assignments/exams/lectures do you remember that had some relation to sustainability and which course was it a part of?
5. What projects have you completed in your time at RHIT? Please supply a brief description of the project. For example: "RHIT330 Policy Brief: Technical research paper over a topic of social importance"

Faculty Survey:
1. In what department do you teach?
2. What courses have you taught or are within your department that recognize or discuss themes/issues of sustainability?
3. For the courses listed in Question 2: Describe what topics of those courses have a relation to sustainability. How long is spent throughout the quarter discussing these topics?

4. For the courses listed in Question 2: What are the major projects within those courses that could be related to sustainability?
5. What courses within your department or that you've taught could potentially implement topics of sustainability?
6. Any other faculty to talk to?

The survey was administered through in-person interviews and an online survey sent by email. There is an assumed bias of those who would respond to the survey or complete an interview are those individuals are typically more inclined towards incorporating sustainability into their education than the general population at RHIT. The purpose of the survey was to identify areas of sustainability education and topics of sustainability within the course curriculum, though lead to additional discussions which indicate the underlying complexity and challenges with implementing education in sustainability.

From the survey, a wide variety of majors were represented in the 28 student respondents. These respondents of the 2,081 reported undergraduate enrolled students in Fall 2021 [3] represented the following majors:

- Biochemistry
- Biochemistry & Molecular Biology
- Biology
- Biomedical Engineering
- Chemical Engineering
- Chemistry
- Civil Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Engineering Physics
- Mechanical Engineering
- Optical Engineering
- Software Engineering

No major had more than six student respondents. Of these 28 students, eight could not identify courses they have taken related to sustainability. fourteen of the students identified at least 1 C-Tier (or higher) course. Seven of the 28 students identified at least one A-Tier course. For clarification, the respondents did not know of the tiered classification of courses. Also, there are limitations to the number of students able to take these courses. For example, in the 2022-2023 school year, Introduction to Environmental Science saw one section offered for the year to accommodate 24 students. Introduction to Sustainability sees a similar limitation with one section opened for 15 students. Assuming the 24- and 15-person cap in these courses for four years of unique students, then the student body of 2,081 students can see up to 156 students within these two A-Tier courses. The potential maximum exposure of 156 students stands at less than 10% of the student body yet 25% of survey respondents have exposure to an A-Tier course in the survey.

From the faculty survey, there was a bias that 10 of the 21 respondents were associated with the Chemistry and Biochemistry (5) or Chemical Engineering (5) departments. The faculty had 15 of the 21 respondents specifically identified two or more courses within their department that taught subjects of sustainability. Only one respondent, from the Computer Science and Software Engineering Department, did not identify any courses within their department related to sustainability. Additionally, 19 of 20 respondents to faculty Question 5 were able to identify specific courses which could grow to include sustainability topics (the remaining respondent is an Electrical and Computer Engineering faculty member).

Through these interviews, various insights were gathered through conversations that went beyond the questions of the survey. One such insight is a separation of pieces of sustainability education. RHIT has an existing framework to enhance and deliver a sustainable design and innovation aspect of education while finding difficulties in prioritizing sustainability-related social equity and justice education. Another insight is a separation of the concept of sustainability and the moral imperative behind sustainability. There are the capabilities to teach a technical and analytical aspect of sustainability separately from teaching social sustainability. The individuals taught, just as they are taught numerous skills throughout their major, choose for themselves whether to incorporate their education into their work. Another insight indicated that design, material, and project-intensive courses include opportunities for sustainability education more prominently than foundational engineering courses designed for understanding.

Peer Institution Assessment

One can look outside of RHIT's curricula to identify opportunities for future improvement by obtaining insight from other peer institutions. Select schools who thrive as recognized sustainability-minded schools were identified, and publicly available information was gathered about the schools' sustainability education. When accessible, interviews with students of the institution were conducted to get a better understanding of the student experience of sustainability within the institution.

RHIT, with the A-Tier and B-Tier courses listed above, holds 36 sustainability courses for its campus population of 2,081 [3]. Sustainability is well-incorporated in specific majors whose processes more predictably necessitate sustainability education (Civil and Environmental Engineering or Chemistry and Biochemistry, for example). The visibility of sustainability courses outside of these majors is limited. Topical courses such as Mechanical Engineering's Renewable Energy and Electrical Engineering's Sustainable Energy Systems exist in other majors. RHIT offers a Minor in Sustainability program.

Franklin W. Olin College of Engineering (382 students as of Fall 2021) [3] hosts a highly flexible curriculum which guides individuals towards an engineering or project management career. The institute's unique focus on project-based learning combined with a focus on innovation and entrepreneurship opened multiple paths for implementing sustainability education. Through the advocacy of their small student body, the college invested into a sustainability concentration for their engineering major – including numerous advanced courses in topics such as biomimicry, renewable energy, environmental consulting, sustainable design,

and affordable design and entrepreneurship [4]. Specific course offerings were not found on the school's public website.

California Polytechnic State University San Luis Obispo (21,093 students as of Fall 2021) [3] has an extensive range of sustainably related sources with an emphasis on hands-on learning. Strong industry partnerships enable coursework in specific sustainability-oriented industrial projects. The school associates 17 bachelor's degrees, 21 concentrations and minors, and 4 master's programs with sustainability through topics such as environmental sciences, public policy, sustainable agriculture, industrial technology, management, etc. [5].

University of Illinois Urbana-Champaign (34,779 students as of Fall 2021) [3] supports many disciplines at the undergraduate and graduate level with numerous certificate programs and research opportunities focused on sustainability. The school has 192 publicly listed courses in sustainability on top of strong research programs. Its research opportunities have led to significant contributions in sustainable technologies, environmental science, renewable energy, and sustainable agriculture. The university's Institute for Sustainability, Energy, and Environment offers nine bachelor's degrees, four minors, nine graduate majors, and one graduate minor in areas of urban development, civil and environmental engineering, environmental science, energy systems, etc. [6].

The Georgia Institute of Technology (17,447 students as of Fall 2021) [3] primarily focuses on a highly refined sustainability education on sustainable technologies and urban planning, imbuing sustainability-driven innovation within these topics. The school has outlined education for sustainable development and leading sustainability research as two of six major targets in the school's "Sustainability Next Strategic Plan" [7].

Colorado School of Mines (5,491 students as of Fall 2021) [3] offers a specialized focus on sustainable resource management and environmental stewardship and brings a well-designed interdisciplinary collaboration between its various centers and institutes. Institute E offers four opportunities through its Sustainability Energy Undergraduate Distinction Program, Energy minor, opportunities with focuses on humanitarian engineering, and an honors program in public affairs [8].

Rochester Institute of Technology (14,000 students as of Fall 2021) [3] provides diverse opportunities in sustainability education across disciplines with a reported 74% of departments offering courses related to sustainability. The institute has bachelor's and master's degree programs in environmental sustainability, health, and safety, as well as a master's program in sustainable systems. Additionally, students can earn a PhD in sustainability, which is an interdisciplinary program that includes policy and economics along with environmental assessment [9].

Integrating Sustainability into Engineering Education

Implementation of sustainability into curriculum is an ongoing field of research as multiple arising standards and goals adjust what changes are necessary to provide scholars with the tools

necessary to create meaningful change. One such approach to implementing sustainability revolves around the United Nation's Sustainable Development Goals (SDGs) as established in *The 2030 Agenda for Sustainable Development* [10]. These SDGs focus on human and environmental health to balance improvements to quality of life for humans and improving planet health. Engineering education is challenged to incorporate these SDGs and recognize the scope of their projects extend into large complex systems. Education that cooperates with SDGs "will require wide-ranging skills, lateral thinking and knowledge transfer between various social, life, and physical sciences as well as engineering disciplines" [11]. Thus, engineering must extend far beyond the technical experience to solve low-level problems. The social challenges of societies, need for health care, addressing climate change, energy production, overconsumption, water pollution, waste production, hunger, infrastructure, and additional topics create a foundation for engineering innovation to flourish in tackling the SDGs.

Tactics to implementing sustainability goals set by SDGs or other targets for sustainability continue to recognize multiple transferrable skills that must be taught to create well-rounded scholars. Engineering for One Planet targets learning outcomes related to systems thinking, knowledge of the three pillars of sustainability, technical outcomes for environmental impact and life-cycle assessments, and leadership skills to influence change in a transition to environmental sustainability [12].

Ramirez-Mendoza et. al. advertises the importance of a well-understood and wide-reaching message of implementing SDGs into curriculum. Not only will a wide variety of topics be ingrained into engineering education, but student experiences must reinforce this learning. Options exist to create a "living laboratory" out of the campus "for the implementation and deployment of [SDGs]" [13]. Implementing SDGs into project work often demands localized and unique solutions acknowledging the greater system which any project exists within. A systems thinking and entrepreneurial mindset offers the potential to identify needs and design innovative solutions in the realm of sustainability. SDG-oriented course learning objectives can direct and motivate inclusion of topics of sustainability within course material and teachings [14].

As with any topic of education, any designed learning outcomes must be measured for successful student comprehension. Redman, Wiek, and Barth recommend identifying which reason which tools should be used and how to connect learning outcomes with the tools used with a psychometric model. Tools vary from student self-assessment, reflective writing, case studies, focus group interviews, performance observation, conventional testing, and regular coursework [15]. These varying methodologies of tools can offer insights into how competent students are in the realm of sustainability, so those selecting tools should be holistically assessing the topics of sustainability. For example, one such tool, the Sustainability Matrix, aims to interpret competences in resource consumption, design, impacts, and risks for each pillar of sustainability [16].

Recommendations and Future Areas of Investigation

After the analysis of RHIT's course curriculum, alongside student and faculty input and reviews of peer institution capabilities and documented approaches for incorporating sustainability in education, the following recommendations arose as areas of potential enhancement for sustainability education at RHIT.

To enhance sustainability education, RHIT could consider expanding its environmental science curriculum by introducing additional courses covering topics such as climate science, environmental policy, atmospheric sciences, ecology, and sustainable resource management. This is not to say RHIT does not have these topics available within the curriculum, but that no degree focuses on areas of the environmental sciences. This expansion would further enable students to obtain a solid foundation in environmental science principles which can correlate or enhance the any additional education in sustainability topics.

Additionally, improved visibility of sustainability curriculum and opportunities could be implemented to promote sustainability education at RHIT. An online platform or dedicated section of the university's website could serve as a central hub for students to easily access information on sustainability courses, research projects, internships, or other relevant opportunities. Furthermore, promoting sustainability-related events, guest lectures, or workshops can create a vibrant sustainability community.

The implementation of sustainability education must come with identified goals related to topics of sustainability and well-monitored through the use of tools to measure student sustainability competences. The data obtained from an effective tool can inform of any under-performing competences so curriculum and coursework can be improved. Strong sustainability education will adjust how engineers understand their work and expectations as an engineer. As such, the implementation of sustainability education must be closely monitored and persistently improved and enforced so engineering students can succeed in the realm of sustainability.

Lastly, active partnerships with sustainability-focused organizations can allow students to engage with potential employers prioritizing sustainability. The exposure can encourage students to consider career paths where they can contribute to sustainable practices while bringing a positive impact through their engineering talents. Additionally, real-life experiences obtained through these partnerships can also bring revisions or improvements to course projects seeking a focus on sustainability within that engineering discipline.

These recommendations are suggestions to bring more robust and impactful sustainability education to the students at RHIT. They look to strengthen our commitment to sustainability while maintaining the goals of the institution to equip its students with the skills to address the complex challenges of our global society.

Additional areas for future investigation include:

- How do individual departments incorporate sustainability education within their expected student learning outcomes?

- What level of administrative support is necessary to successfully reach education goals for sustainability?
- Where can interdepartmental education best enhance discussion of sustainability?

Conclusion

Having examined the baseline of sustainability education at RHIT and reviewed the availability of sustainability education at other peer institutions, this assessment provides an initial understanding of the current opportunities at RHIT. By acknowledging the existing efforts and identifying areas for improvement, further advancements in sustainability education can align with the institutional strategic plan goals to enhance sustainability education at RHIT. As more courses integrate sustainability in their curricula, these courses can be mapped throughout degree programs to track touchpoints of sustainability in any major. Additionally, other institutes of higher learning can gain insight from this assessment and recommendations for future improvements that may be applicable within their own campus community. Such background research educates further decisions in the areas of future investigation as individual departments and administrative look towards integrating sustainability throughout RHIT's curriculum and culture. Collective efforts and a commitment to continuous improvement can enable RHIT to be leaders in educating sustainability and addressing sustainability-related global challenges.

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