Activity Based Learning for Inculcating Awareness About Sustainability Among First Year Engineering Students

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***Abstract*— Sustainability competency is an essential component in engineering education and engineers with multiple competencies are in demand globally. Engineers are important players in adapting the latest technology sustainably. Undergraduate students, who are future professionals, can use engineering education for development of the modern sustainable world and they must acquire such skills. They need to be prepared to work in teams and think critically to solve complex problems with sustainability principles in mind. Cognitive, affective, and behavioral competencies are highly needed in skilled professionals and it is not easy to develop them through traditional teaching methods such as lecturing. Activity based learning is an effective approach for developing these competencies. This paper reports an effort to create awareness about sustainability in engineering education by undertaking multiple activities (carbon footprint, energy audit , mind mapping, sustainable designing etc.) for first year engineering students at an autonomous Engineering College in Maharashtra under Project Based Learning course (PBL). From the assessment of the activities, it was clearly demonstrated that students developed good understanding of sustainability and actively participated in all the activities and suggested various interesting measures to reduce carbon footprint and electrical consumption. They also used the sustainability principles in designing and implementation in their PBL projects at the end of the semester. Thus, PBL can be considered as a practical and innovative pedagogy to effectively support core values of sustainability such as participative learning, critical reflection, systemic thinking, and creativity.**

***Keywords*— First-Year Engineering, Sustainability, Activity based learning, Curriculum Development, Student Engagement.**

***ICTIEE* Track*:* Curriculum Development**

ICTIEE Sub-Track: Transforming First-Year Engineering: Redesigning Curriculum for Lifelong Learning and Student Engagement

I. INTRODUCTION

IN today's scenario it is essential to empower students with the competencies needed to tackle both individual and societal problems and contribute meaningfully to resolve complex global challenges. Majority of these global issues have highlighted the significance of fostering a collective effort toward responsible action.

Engineering education plays a crucial role in preparing the younger generation to confront both individual and global challenges with resilience, adaptability, and a commitment to positive change through a holistic and interdisciplinary approach contributing to a more sustainable future.

Considering that, the education for sustainability is deemed crucial in cultivating individual awareness in a dynamic manner, rather than merely transferring pre- prepared information to students (Warburton 2003). This matter is being addressed in PBL course introduced for first year engineering students with the core idea of actively involving students and advocating a comprehensive understanding of sustainability through activity based learning. Problem-based learning (PBL) is a practical and innovative approach that motivates the learners to be actively involved in the learning process through collaboration and sharing of knowledge. Application of this method can show remarkable changes in students' learning as they are expected to be more active participants in the learning process, involved in acquiring soft skills such as teamwork, presenting their work, responsibility, and time management, etc.

II. BACKGROUND

UNESCO and the UN's Sustainable Development Goals have identified the critical role of engineering in achieving sustainable forms of development, and there is a need to analyze the design, features, and nature of sustainability-focused initiatives in engineering education (as suggested by Kaur J. et al, 2022) Until now, few studies have identified the knowledge gaps in this sector of higher education. Since sustainability is closely related to complexity, innovation, and interdisciplinary approach, it requires alternative pedagogy rather than traditional, lecture-based content delivery.

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Studies have documented that Problem-Based and Project-Based Learning (PBL) can be an innovative pedagogy for sustainability education (Lehmann et al., 2008). Therefore, it is becoming increasingly recognized that there are interwoven relationships between PBL, innovation, collaboration, interdisciplinary, and sustainability. In recent years, a wide range of exploration has been put into practice in higher education, including approaches for educational change to PBL, group project assessment in the PBL environment, and factors influencing group creativity in project-organized teams. However, more studies are needed to provide more substantial evidence of these relationships, as is more research on the value of PBL in relation to the sustainable development of higher education itself. The related literature review indicated that most of the researches focused on the environmental aspect of sustainable development. It was further observed that the awareness of students regarding sustainability and the related concerns was much less as compared to their awareness regarding environment-related concerns. In most of the researchers the concept of environmental sustainable development was misrepresented as environmental education. Significant knowledge gaps concerning the social and economic dimensions were pointed out in a number of studies.

III. Motivation

In the process of curriculum revision in 2020, the college introduced an elective in the first year Engineering curriculum where students were given a choice of courses as Engineering Exploration and Environment & Technology in one of the two semesters. The course of Engineering Exploration focused on Basics of engineering design, mechanisms, platform based development and a course project. The necessary theoretical background was covered in theory class along with in class activities while most of the contents were covered through well designed group activities. For the course project, students were expected to design and create a prototype based on any one of the given themes. The course was developed for freshmen with objectives of Identification of need and connecting it to technology and development of Project while learning new concepts. The Course was taught with the concept of co- teaching by faculty members from different branches.

The course of Environment and technology was designed with an objective to sensitize the students towards the environment along with emphasis on engineering applications required for environmental preservation. Learner was acquainted with various environmental assessments and monitoring tools for addressing environmental concerns. The mini project was also part of the course where students submitted survey projects or prototypes.

From experience during AY 2020 to 2022, the maximum number of students opted for engineering exploration as their first choice mainly due to activity based learning and prototype development. Since environment studies are introduced from elementary schools, students were reluctant to opt Environment & technology as a choice. Also the college had limited resources for conduction of Engineering Exploration for all hence could not be offered to all. Another difficulty faced by the students and faculty members that since the course was conducted only for one semester and for 2 hours per week, , it was difficult to complete the project and attain the intended outcome especially in the first semester .

Hence in the next curriculum revision in AY2023, college planned to offer course to all students in first year.

IV. Curriculum design & Implementation

The course named as 'Project Based Learning' in AY 2023-24 was revised with the following considerations.

- Provision for all First Year students extend over 2 semesters
- Inculcating importance of sustainability in engineering profession
- Introducing robotics to keep pace with recent trends
- The hands on group or individual activities planned throughout the course
- A group project at the end of second semester

The course was designed with following modules

1. Introduction to Project Based Learning (PBL)- Introduction to Engineering projects, design thinking, Basics of project management
2. Engineering Design and Exploration-Engineering design process, Mechanisms, Sensors, basic Arduino programming
3. Robotics and Automation- Industrial Revolution, technologies for automation
4. Sustainability Solutions- Focus on SDGs 7,9,11,13,14,15 i.e. Affordable and clean energy, Industry, innovation and infrastructure, Climate action, Life below water and Life on land. Awareness and activities to understand importance and use some of the considerations in the project.

A. Implementation details

The course was implemented in AY 2023-24 with total of 840 students across seven different branches of study, the class had typically 70 students and it was divided into 14 groups with 5 students in each group. The class was handled by 6 faculty members in every class with different domain expertise. With respect to module 4 of syllabus, following activities were identified to address sustainable solutions.

1) Awareness about all SDGs

Importance of all Sustainable goals and role of engineers in society towards these goals was discussed. A minute paper activity was conducted and every student was asked about his/ her thoughts about this aspect.

2) Carbon Footprint Calculation

Carbon footprint refers to the total amount of greenhouse gases (GHG) emitted by an activity, individual, company, or country into the atmosphere and are measured in terms of tons of carbon dioxide equivalents (CO2e) per year. Carbon footprints include both direct and indirect emissions from our daily activities, such as using electricity, driving a car, or

disposal of waste. Carbon footprints will help people identify and reduce GHG emissions, raise awareness of environmental costs, and manage their energy and environment. Students were made to understand that our daily activities are greatly responsible for an increase in greenhouse gas emissions in the atmosphere, ultimately contributing to global warming and climate change. To comprehend the same in a better way, they were asked to calculate their carbon footprint. They were provided with a worksheet to enter the details of their activities, details of manual carbon footprint calculation and the links of online carbon footprint calculators developed by Tata sustainability group, carbon footprint Ltd, Tata power, Umang, Government of India etc.

Students performed the activities in group and submitted a group assignment.

Statement Given:

Calculate your carbon footprint, compare it with global average and list various measures that you will adopt to reduce your carbon footprint.

Evaluation Criteria:

1. Calculations of carbon emissions from electrical consumption and transportation
2. Adaptable ideas for reducing carbon footprint
3. Student reflections and learning outcomes

The main objective of the activity was to make them aware about their responsibility as global citizens and share ideas how they can make a difference in reducing GHG emissions. Students calculated their carbon footprint manually as well as using online carbon footprint calculators and computed the GHG emissions done by them. After calculating their footprint they compared it with the Indian and the global average carbon footprint and suggested various measures to reduce their carbon footprint (Fig. 1).

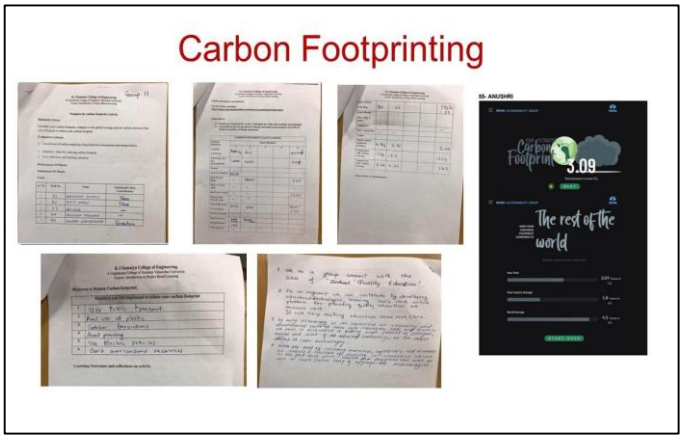

Fig.1. Carbon footprint calculation done by students.

3) Energy Audit:

An energy audit is a systematic way to calculate energy consumption in any premises and identify potential opportunities to save energy. It is the first step towards making your home, school or any other area more energy efficient. Energy audits help in identifying possible feasible ways to reduce energy costs and carbon footprint, and can also lead to innovation and improved productivity. For the class activity students were given a worksheet with list of various household appliances with power (Watts) and the formulae for electricity calculations. Students were clearly instructed to put the actual power wattage of appliances at their home to get the correct value of electricity consumption. Students calculated their individual household electricity consumption manually. Depending on their individual consumption, they suggested methods they can adopt to save electricity. They also calculated the numbers of solar panels required for the same amount of electricity consumption and estimated cost for solar installation (Fig 2). Students performed the activities in group and submitted a group assignment

Statement Given:

Task 1- Calculate the total energy consumption for a month for your home.

Task 2- Share different measures that you will adopt to reduce your energy consumption.

Task 3- Estimate the number of solar panels required and the cost of solar installation.

Evaluation Criteria:

1. Calculations of energy consumption for different appliances
2. Total energy consumption for your home.
3. Adaptable ideas for reducing energy consumption
4. Calculation of cost and number of solar panels as a replacement for existing system with solar installation.

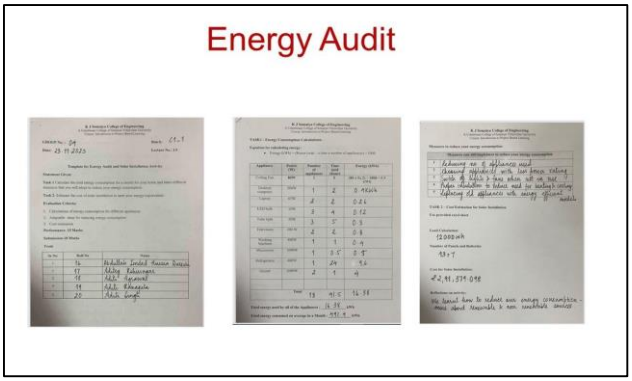

Fig. 2: Sample of Energy Audit Activity done by the students

4) Mind Map:

Mind Mapping is a technique used to organize ideas and thoughts about a concept in the form of a diagram to show relationships between topics and subtopics. It is often used to brainstorm ideas, solve problems, or generate new concepts. It also supports team spirit and opens channels of communication among students. For the mind map activity students were given different topics related to waste management and were asked to provide engineering solutions for different types of waste in the form of mind map on the A3 sheets. They were instructed to initially brainstorm and discuss various possible solutions in the first half of the activity and were asked to draw mind maps using their creativity in the

latter half. Students brainstormed and depicted their innovative ideas on waste management, mainly agricultural waste management in the form of creative mind maps (Fig 3)

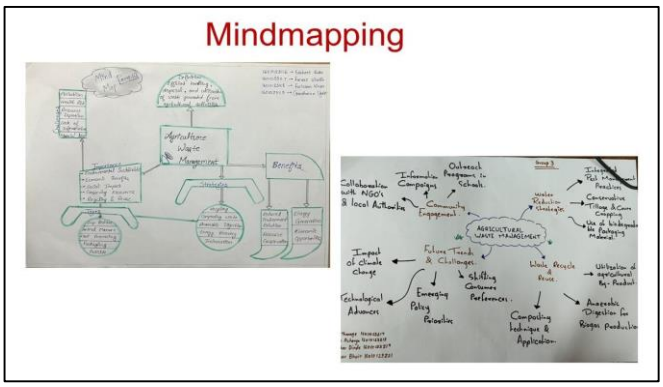

Fig. 3: Mind maps prepared by the students

Statement Given:

Prepare a mind map for waste management system.

Evaluation Criteria:

1. Creativity and Presentation of mind map
2. Clarity of central idea
3. Innovative solutions

Emphasis was given on how they represented waste management as the central idea and the possible innovative solutions as branches and their associations.

B. Course Projects

Students were introduced to the idea of project in semester one and provided with themes based on sustainability goals to work on projects in semester two.

The themes given were as

- Waste management
- Energy management
- Water management
- Healthcare
- Agriculture
- Smart cities

Students worked in groups of 5 each on projects based on the above themes in second term. The actual topic of the project was chosen by an individual group and was approved looking at relevance to theme and feasibility for implementation. Project was evaluated at different stages of implementation from ideation to prototype development.

C. Course Feedback

At the end of both the semesters, course feedback was collected using a Google questionnaire from all students. The Google form was shared with the students via official mail. The questionnaire had questions related to sustainability, team building and other topics covered under the course. More than 500 students have responded to the feedback shared with them.

V. RESULTS AND DISCUSSIONS

The main objective of the study was to inculcate an understanding about sustainability along with team work and critical thinking approach among the first year engineering students, which are the essential skills required among the young graduates.

A. Awareness about SDGs:

At the end of the introductory session on SDGs for highlighting the importance of sustainability, students were given one small activity to jot down their views on sustainability and share their thoughts about how they can contribute to sustainability as engineers. This activity motivated them to discuss in a team and express their views. It helped teachers in getting an idea of their understanding about sustainability.

B. Sustainability Activities (Carbon Footprint Activity, Energy Audit & Mind Mapping) :

All the activities were assessed for 25 marks as per pre-defined criteria which included teacher interaction with the group at the time of activity submission. This was an opportunity for teachers to estimate their understanding and learning about sustainability. Each activity was evaluated for 25 marks , out of which typically 15 marks were for performance in class activity and reflections, 10 marks for report submission. To gauge their awareness about sustainability, marks obtained for each activity in the class were considered as measures of their understanding. Following are observations of faculty members for awareness of sustainability as per student scores in these activities.

TABLE I:
PERCENTAGE OF STUDENTS' AWARENESS ABOUT SUSTAINABILITY

Score (out of 15)	Awareness about Sustainability	% of students as per Scores	
		Carbon Footprint	Energy Audit
12 -15	Good	59	65
8 - 11	Fair	29	20
4 - 7	Average	10	9
0 - 3	Poor	2	6

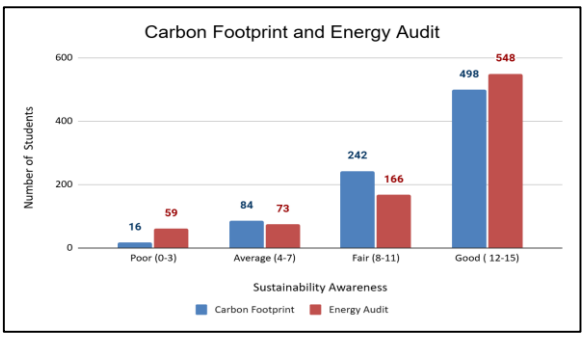

Fig.4. Awareness about Sustainability from Students Scores

Out of 840 students assessed for carbon footprint activity and energy audit activity, around 60 to 65 % students demonstrated good understanding about sustainability, 20 to 29 % showed fair understanding and about 10 % students average understanding about sustainability. Only 2% to 6 % of students were poor performers due to some or the other reason and have shown poor understanding about sustainability. From interactions with students during activities, faculty members observed that students participated and enjoyed all activities related to sustainability and suggested various interesting measures together as a group related to saving energy, reducing their carbon footprint and to manage waste. The activities essentially created awareness about carbon footprint and energy audit but also promoted team work and critical thinking.

C. Course Projects:

Students' project was majorly indicative of their understanding about sustainability, as they were motivated to select the topics for the project with considerations to SDGs. Many students chose projects related to waste management, water management, used recycled material and considered energy conservation in their projects. From Fig 5 it can be seen that about 65% of students chose projects in themes based on sustainability goals and their understanding of sustainability was clearly reflected in the selection and design and execution of their course projects. Project exhibited by them at the end of second semester during PBL project exhibition again supported team building, creativity, critical thinking and their awareness about sustainability.

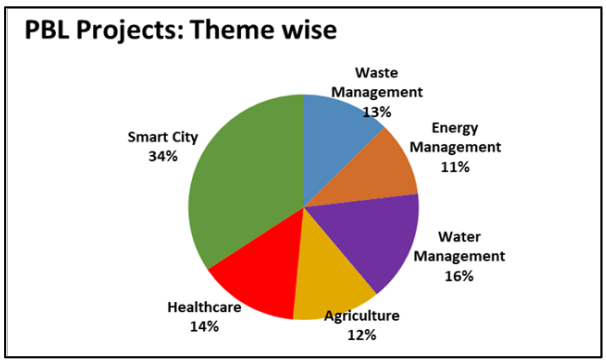

Fig.5. Theme wise project topics distribution

Fig.6. Student explaining the working of their Models at PBL Project exhibition

D. Course Feedback:

Course feedback collected at the end of the semester was another criterion to assess their understanding regarding sustainability, teamwork and execution of activities in relation to module 4 related to sustainability solutions. Among the 535 students who completed the feedback, the majority (92%) of the students agreed with the fact that activities conducted in PBL course assisted in inculcating awareness about sustainability and understanding how as an engineer they can contribute to achieve sustainability. Approximately 37 % students among them participated very enthusiastically in all activities. They all agreed that activities were very helpful in ideas sharing and building team spirit. Most of them were satisfied with the design and implementation of activities conducted under the course. (Fig 7 to 9)

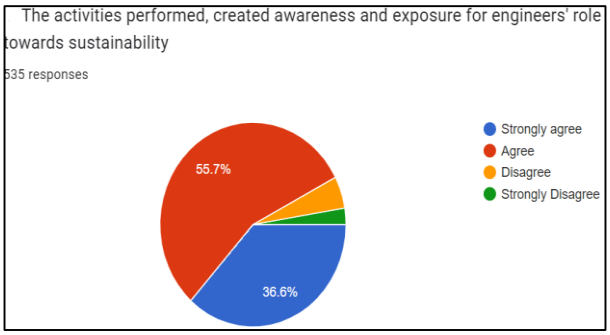

Fig.7 Role of activities in creating awareness about sustainability among students

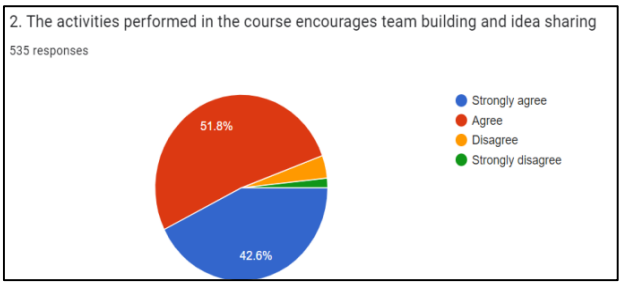

Fig.8 Role of activities in team building and idea sharing among students

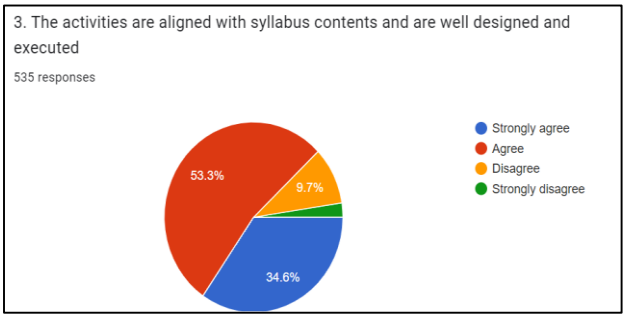

Fig.9 Student's View on Execution of Course Activities

CONCLUSIONS

Our observations after introducing sustainability activities clearly indicated that to a large extent we were able to make our first year engineering students aware about essential concepts like SDGs, carbon footprint, waste management, energy audit and energy conservation, which was reflected in the scores obtained by them in class activities and their selection of PBL projects.

However, majority of curriculums like ours mainly emphasize on environmental aspects of sustainability and the other aspects of sustainability (social and economic dimensions) are usually not touched sufficiently, therefore activities based on those dimensions also need to be included so we can touch upon all the SDGs listed by the United Nations. Another observation was that the majority of the projects selected by students were prototype, we would recommend students to select more survey based projects as they uncover social, economic and environmental facts that may not be immediately obvious, or of which students may be unaware.

Implementing a new curriculum with different pedagogy is usually complex and has hidden challenges, whether it is in terms of preparedness of faculty members from various disciplines to cater to concepts of sustainability or reduced student attention span. Keeping the challenges in mind we faced, we suggest following measures for implementing sustainability related activities in class.

1.Training of faculty members prior to conducting activities

2. Small duration of the activity

3. Including activities for social and economic concerns of sustainability.

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