PHILOSOPHY OF ENGINEERING: A MOTIVATION COURSE FOR FRESHMEN ENGINEERING STUDENTS

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ABSTRACT

All undergraduate engineering curriculum are centred to impart technical skills and knowledge, assess students' ability to apply these skills and knowledge. The curricula lack courses that enlighten the students about engineering occupational categories, desired attributes for each occupation category and enable them to philosophically analyse the nature and impact of these occupations. This void causes lack of motivation among students in learning technical skills and knowledge in general. To address this gap, a mandatory course titled "Philosophy of Engineering" is introduced and offered to freshmen students of all engineering disciplines. This course provides the students a comprehensive outline of engineering, role of engineers, connection between engineer and society, need for conceive, design, implement and operate skills to solve complex industrial or societal problems. The course is delivered by a team of faculty for interdisciplinary engineering students using flexible and student led active learning techniques in every session. As a part of this course, interdisciplinary student groups are formed and given a task to conceive interdisciplinary engineering ideas for solving the local community problems. This activity enabled the students to think critically and creatively during their first year of study. In line with the indented course outcomes and student led learning activities, students also give input on assessment tasks and related assessment criteria. Students feedback on the course is obtained through direct and indirect methods. The students realize it engaging, compelling to learn more on engineering and have given positive feedback on the context and purpose of the course. This paper describes the design and development of this course using ADDIE (Analyse Design Develop Implement and Evaluate) and Understanding by Design (UbD) models.

KEYWORDS

Philosophy, attributes of engineers, interdisciplinary, sustainable development, Understanding by Design, ADDIE model, Standards: 1, 2, 3, 4, 5, 7, 8, 11, 12

INTRODUCTION

A working group was formed at SRM Institute of Science and Technology (SRMIST) to perform gap analysis in present undergraduate engineering curriculum. In the past, the working group had analysed gaps between desired and actual curriculum to improve student learning outcomes and meet program educational objectives. To fill the gap, new courses were introduced with contemporary discipline specific knowledge and skills for industry and societal needs. This time, before performing curriculum gap analysis, the working group had conducted an exit survey from graduating undergraduate engineering students on curriculum, education in terms of quality and experiences. According to the survey results, about 40 percent of the graduates have mentioned that the existing curriculum lack motivational courses that enlighten them about role of engineers, engineering occupational categories and desired attributes for each occupation category. The working group had identified this void that causes lack of motivation among students in learning technical skills and knowledge in general. To address this gap, a mandatory course titled “Philosophy of Engineering” is introduced and offered to freshmen students of all engineering disciplines. ADDIE model was chosen to Analyse, Design, Develop, Implement and Evaluate this course (Tu, Zhang, & Zhang, 2021). This work addresses CDIO standards 2, 7, 8 and 11 on Learning Outcomes, Integrated Learning Experiences, Active Learning and Learning Assessments.

The structure of this paper is organized as follows: (a) Analysis (b) Design (c) Development (c) Implementation and Evaluation of the course (d) Conclusion.

ANALYSIS

The group analysed various frameworks for designing this course such as Universal Design of Learning (UDL), Integrated Course Design (ICD) and Understanding by Design (UbD) frameworks. The UbD framework recommends that the instructors should focus on the learning outcomes and assessments in line to the outcomes prior to the design of teaching and learning activities (Wiggins & McTighe, 2005). For this reason, the group had considered this UbD approach for designing this course than the traditional approaches. Before designing this course, a comprehensive outline is created as follows: engineering, history of engineering development, role of engineers, engineering occupational categories, desired attributes for each occupation, connection between engineer and society; ontology, epistemology, methodology, axiology of engineering; need for Conceive, Design, Implement and Operate (CDIO) skills to solve complex industrial or societal problems.

DESIGN

Understanding by Design otherwise called as Backward Design framework is typically used for designing curriculum, courses and learning contents in each unit. In contrast to the forward design approach, the backward design approach first considers the learning outcomes of the course which is in compliance with CDIO Standard 2 – Learning Outcomes. These learning outcomes address the knowledge and skills that the students will understand and perform after the completion of the course. Once the learning outcomes are articulated, the second stage focus on design of assessments aligned with learning outcomes. The third stage focus on CDIO standard 8 – Active learning i.e. design of teaching and learning activities for each learning outcomes and assessments considered. The design of this course using backward design approach stage by stage are given in the following sections.

Stage 1 – Desired Results

In the first stage, learning objectives or rationale of the course is considered. This stage addresses the following three questions: What students should listen, read, visualize and explore? What knowledge and skills should students enhance as a part of CDIO Standard 7 - Integrated Learning Experiences?, What are big concepts and understandings that the students should retain?. Table 1. elaborates the first stage of the UbD process.

Table 1. First Stage – Desired Results

Established Objectives/Rationale
1. Inspire a holistic overview of engineering 2. Enlighten the methods and methodologies for building ontologies for systems engineering 3. Acquaint with engineering knowledge, building engineering knowledge and value of engineering 4. Upskill the engineering design process in aspects of conceive, design, implement and operate methodology **5.** Instil the role of engineers in society, code of ethics and socio-politics of technology and engineering
Transfer
Students will be able to independently use their learning to • Analyse the relation between Arts, Mathematics, Science, Technology and Engineering and desired attributes of an engineer • Build ontologies for systems engineering using concept/mind mapping techniques • Analyse the knowledge base in engineering, distinctive features of engineering design and RIASEC model • Illustrate the engineering design process for the given application, analyse the requirements of CDIO engineers • Evaluate designs on their environmental and societal aspects and do organizational analysis on professional engineering organizations
Meaning
UNDERSTANDINGS *Students will understand that* • Engineering has evolved to a new dimension from prehistory to the present situation • Engineering has connection with Arts, Science, Mathematics and Technology • Engineers should possess certain knowledge, skills and attitude that are commonly agreed by many countries in the Washington Accord (International Engineering Alliance, 1869). • Engineers use constructivism and connectivism approach to develop engineering applications • Engineers can play various roles in different fields of engineering • Engineers need to conceive, design, implement and operate engineering systems, processes and products • Engineers should follow ethical code of conduct • Engineers play a vital role on sustainable development • Engineers should be a life-long learner and should take part in professional engineering organisation activities.
ESSENTIAL QUESTIONS

Students will keep considering • Define engineering? • Is arts context necessary for engineering? • Illustrate product life cycle using concept mapping or mind mapping tool. • List out various knowledge base in engineering. • What are the four dimensions of engineering? • Difference between scientific method and engineering design. • List various professional engineering organizations.
Acquisition of Knowledge and Skills
Students will know • STEAM Pyramid • Desired attributes of an engineer • Engineering habits of mind • Reference ontology and application ontology • Product lifecycle, commodities, services and infrastructure • RIASEC model • Epistemology of engineering design • Rigour, creativity and change in engineering • CDIO methodology
Students will be skilled at • Reference ontology, engineering application ontology, product life cycle ontology using concept/mind mapping • Case study on RIASEC theory of career choice • Analyse distinctive features of epistemology of engineering design • Conceive engineering ideas for local community problems (conceive skill) • Design, Implement and Operation Process • Illustrate the engineering design process for the given application • Analyse the requirements of operational engineers • Evaluate popular inventions and apply their new point of view to re-design • Case Study on achieving Sustainable Development Goals

Stage 2 – Evidence

The students'learning is evidenced through appropriate assessments and performance tasks. The second stage of UbD framework consider the above tasks by addressing the following questions: How to know whether the students have achieved the desired results? What evidences are accepted for students understanding and proficiency? Table 2. elaborates the second stage of the UbD process.

Table 2. Second Stage - Evidence

Evaluation Criteria
Performance Indicators • For case studies – Uniqueness of the case, analysis/solution options, recommendations, conclusions, presentation skills • For concept/mind mapping – Effective use of tools, no of connections, meaningful links • For case studies on sustainability – Appropriate handprints and footprints of the sustainable goal discussed

• For CDIO project – Identification of problem domain/detailed analysis, study of existing problems, feasibility of proposal
Evidences
• Quizzes • Case study assignments • Poster presentations • CDIO projects

Stage 3 – Learning Plan

The final stage of UbD framework consider the teaching strategies and learning activities to be created by addressing the following questions: What knowledge and skills will enable the students to perform effectively and achieve desired results? What type of learning activities will enhance students' knowledge and skills? What learning materials and resources are to be prepared to attain these objectives? Table 3. elaborates the third stage of the UbD process.

Table 3. Third Stage – Learning Plan

Summary of Key Learning Events and Instructions
In this course BOPPPS model is used to organize the teaching process for each session (Pattison & Day, 2006). The BOPPPS model divides each teaching session in to six stages: Bridge in, Objective, Pre-assessment, Participatory Learning, Post-assessment and Summary. *Bridge in:* This stage is used to attract the attention of students, make them think critically, help them to focus on the topic to be learned. Strategies used in this stage are motivational videos, brainstorming, storytelling. *Objective:* In this stage, student know about the purpose of this session learning and its focus direction. *Pre-assessment:* This stage is to understand the existing knowledge of the students on the topic to be learned and will enable them to construct the knowledge through deep learning. The strategies used are brainstorming, word cloud, quizzes. *Participatory Learning:* This stage brings active participation of the students through learning activities aligned with the intended learning outcomes (Biggs, 2014). The strategies used are inquiry-based learning group discussions, debates, think-pare-share, jigsaw, poster presentation, case study, concept/mind mapping, snowball, worksheet, problem based learning. *Post-assessment:* This stage is to understand whether the students have learned the concept and attained the intended outcomes. The strategies used are quizzes, one minute paper, muddiest point. *Summary:* This stage enables the students to connect learnings and reflect on the learning. The strategies used are recall and review through comments. As a part of this course, interdisciplinary student groups are formed and given a task to conceive interdisciplinary or interdisciplinary engineering ideas for solving the local community problems. This activity enabled the students to think critically and creatively during their first year of study. Only conceive part in the CDIO skill is evaluated in this activity using a grading rubric.

DEVELOPMENT

In the development stage, all the elements of the course are assembled. The philosophy of engineering course is an integrated 3 credit course with 2 credits for lecture and 1 credit for practice. The total hours of engagement per semester is 60 hours. The course contents and learning activities designed in the design phase are structured session wise to check whether the course can be completed within the scheduled hours of engagement. Once the contents and activities are fit into the structure, learning materials including reading materials, presentations and videos with animations are developed using ICT tools by the subject experts for the learners with different learning styles (Rajeev & Vairavel, 2021). The faculty members at SRMIST are well trained in developing learning materials, instructional strategies and assessments using ICT tools as a part of faculty teaching competency development framework fulfilling CDIO standard 10 – Learning Assessments (Rajeev & Vairavel, 2023). Assessments including quizzes, worksheets, assignment tasks, case studies, topics for groups discussions and debates with evaluation rubrics are prepared for the entire sessions planned. The learning materials and assessment tasks are uploaded in learning management system before the commencement of the learning sessions. The societal problems for conceiving ideas exercise are identified through collaboration with local non-governmental organizations.

IMPLEMENTATION AND EVALUATION

To impart interdisciplinary learning from first year onwards, students from all the engineering disciplines in equal are assigned in each class of size 40. The course is delivered by a team of faculty (two per class) for interdisciplinary engineering students using flexible and student led active learning techniques in every session. Students also decide the assessment tasks, and corresponding assessment criteria. Even though BOPPPS model is adopted for all the sessions, activities in the stages of the model are led by the students. Due to student-led-activities in most of the sessions, the expected plan for a week may slightly vary and is covered in the forthcoming weeks with the knowledge of students. A keen focus has been kept on the activities that engages students to think critically and enquire philosophically.

Inculcating concepts related to the philosophical aspects of engineering such as ontology, epistemology, methodology and axiology helped the students to think critically and enquire philosophically the scope and purpose of engineering. The entire course is centred on the concept of engineers and the society and most interesting part in the course as per the students' feedback is historical development of engineering in solving societal needs. Students have raised more questions philosophically and shown interest to develop more engineering applications for the benefit of the society. Interdisciplinary engagement in the class enabled the students to understand the diverse nature of engineering and opened up interesting discussions on interdisciplinary project ideas inside the classroom.

The learning experiences shared by the freshmen engineering students of strength 5000 are really encouraging. The summary of the feedback given by the students in the mid of the semester is shown in Figure 1. The performance indicators considered for feedback analysis are course content (whether its inspiring to pursue engineering), student-led-activities approach, solving societal problems, assessment and evaluation methods. The analysis shows that more than 70 percent of the students are highly motivated through this course to pursue engineering with clear idea. With respect to student-led activities, 30 percent of the students have given excellent, and 40 percent have given very good, this is due to the time consumed in preferring the activities and deviation in the learning plan. This student-led approach will be improved with proper planning in advance of each session. Almost 70 percent of the students could conceive ideas for the societal problems through scaffolding and only 15 percent could solve independently without guidance. Being a freshmen student, this result was expected earlier and students now have clear idea about conceiving ideas for the problems in the future. Above 80 percent have given excellent for assessment and evaluation methods used which will be improved further by including more varieties of assessments in the upcoming sessions.

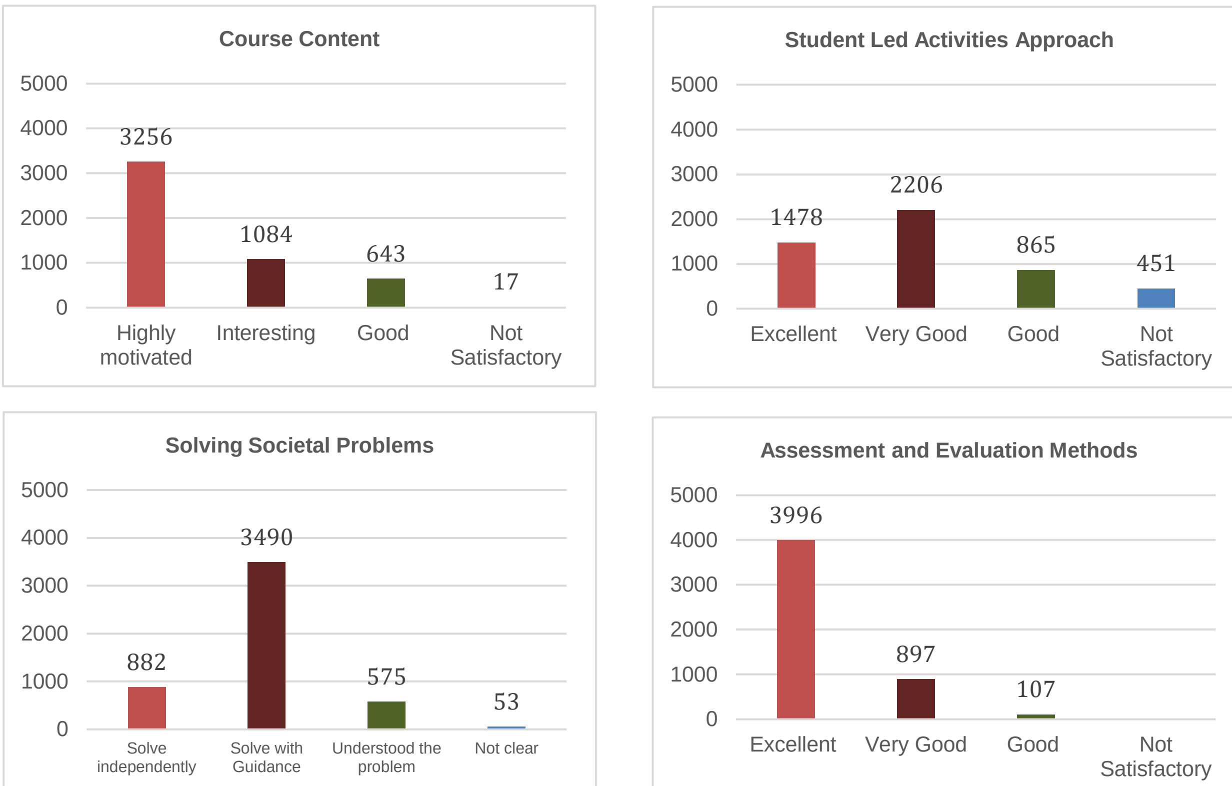

Figure 1. Feedback Analysis

CONCLUSION

This paper gives a detailed need analysis, design, development, implementation and evaluation of a new course titled philosophy of engineering for all freshmen undergraduate engineering students. Students find this course highly motivational towards engineering and pursue engineering program with clear idea. Upon successful completion of this course, the freshmen students gain deep insight on engineering, role of engineers and their desired attributes, connection between engineer and society; ontology, epistemology, methodology, axiology of engineering; need for Conceive, Design, Implement and Operate (CDIO) skills to solve complex engineering problems. The course also enhances critical thinking, creative thinking skills, philosophical enquiry and engineering mindset among the students with quest to solve societal problems using ethical standards and sustainable development methods. As a part of continuous improvement of the course, student-led approach and other areas of improvement will be identified and augmented in the future.

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BIOGRAPHICAL INFORMATION

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