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Problem-Based Learning for Critical Reflections on Skill-based Courses Using DEAL Model

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Abstract : Higher education institutions focus on improving both soft skills and engineering proficiencies among students. The learning progress requires a systematic assessment to know the areas of improvement to meet global competitiveness. Self-reflections and critical reflections on knowledge, skill, and behavior are crucial for an industry-ready graduate. Our work deals with conceptualization, course design, and rubrics design to achieve critical reflections on the graduate outcomes of the students. We have designed the rubrics to assess the behavioral and engineering skills needed to solve complex engineering problems that can be solved better as a team for life-long learning and developing ethical interpersonal skills. Our assessment patterns also helped students achieve higher-order thinking skills through experiential learning.

Keywords : Behavioral assessment rubrics; Complex engineering solutions; Experiential learning; Problem-based learning

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1. Introduction

Present day education system goes through a plethora of changes in terms of teaching-learning methodologies and pedagogies. It is also a roller-coaster for the students to understand the strategy and excel in the new, ever-changing education system, and the saying goes as follows.

"The species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself." It is with the faculty and the students to embrace the change and adapt to newer methods. As the teaching-learning system changes, there is also a need to change the assessment pattern. The assessments have to align with the program outcomes specified for satisfaction-driven learning.

With the resources available to the students, gaining theoretical knowledge alone cannot be a measure to satisfy the Program Outcomes (POs). Realizing the theories learned over time in several semesters via a problem is crucial in developing an interest in engineering and attaining the POs. The students have to take up a problem, identify and analyze the requirements, and later learn and apply the theories into practice.

This way of approaching the problem is called complex engineering. As a formal definition, it can be formulated as a problem that is not fully framed and is left for the students to accomplish its solutions. This learning approach may lead to finding solutions to several socio-economic problems.

In this work, we have developed a new assessment pattern for the students as they move from outcome-based education to Problem-based learning to solve complex engineering problems. One course module has been elaborated on the verticals of learning through experiments, assessments via projects to develop their higher-order thinking, and rubrics for the assessment pattern.

2. Background

The program outcomes that contribute to achieving the complex engineering problems, societal needs, and lifelong learning are elaborated and diagrammatically represented in Figure 1. These attributes contribute to personal, professional, and societal growth.

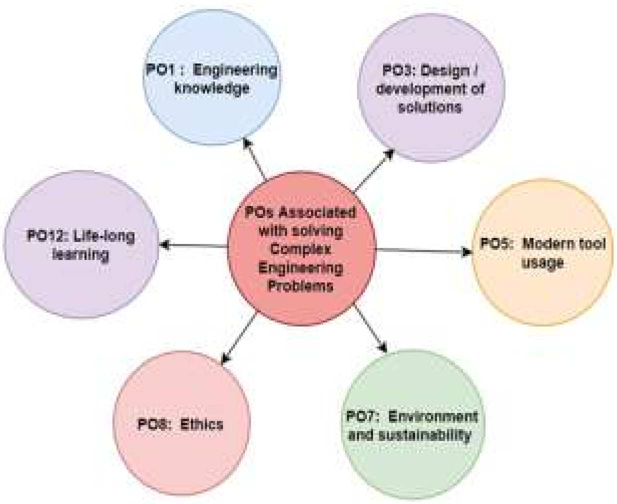

Fig 1: POs and Complex Engineering problems

The elaborate description of each of the POs are as follows,

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Soft skills and behavioral skills are essential to have a better positive outcome in learning (Drysdale & McBeath, 2018). It was also found that low self-confidence and efficacy in approaching a problem affects students' ethical behaviors and tends to show academic dishonesty (Alhadabi A & Karpinski AC, 2019). Giving students a platform for self-efficacy by effective teaching and assessment patterns is highly needed for a better graduate (Wahyudiati et al., 2020). Thus, it is high time we modify our assessments in every aspect on graduate outcomes rather than just theoretical knowledge.

The approach to problem-solving can be improved only with developments in critical thinking through daily experience with peers (Spector, 2019). There has to be problem exploration, testing, conclusions, revisions of ideas, and finally, a project on societal good by every student in their learning.

Table 1: Literature in Problem Based Learning

Literature	Teaching - Learning Goals
(Temel, 2014)	Real-world examples , along with classroom teaching
(Overton and Randles, 2015)	Developing solutions to unstructured real-time problems
(Siew et al., 2017)	Scientific creativity from preschool
(Nadea, B & Naibaho L, 2020).	Improvement in critical thinking among students
(Saputro et al., 2020)	Improve self-efficacy and critical thinking in higher education.

Several works used problem-based learning, one of which was explored by (Kuvac & Koc, 2018) to explore the solution to environmental issues and develop in-depth knowledge in the area among the students. Some of the other kinds of literature associated with the study are listed in Table I.

3. Problem-based Learning

Graduate attributes are the higher-order qualities that students acquire through their learning experience at a university. They include Knowledge, Skill, and Attitude, wherein knowledge is gained via classroom teaching. Nevertheless, the most critical aspects, skill, and attitudes are not taught but have to be gained by practice. Skill development in one's discipline can evolve when the students are given a structured problem and equipped as problem solvers. The ability to analyze use modern tools and peers with ethics in mind can be gained through experiential learning. Similarly, cognitive skills can be upgraded via problem-based learning and prior theoretical knowledge, assumptions, and experiences.

Thus, problem-based learning is the subdomain of Experiential Learning, which brings us down to identifying a problem that is comprehensible, analyzable, and manageable within the course. As graduates, they need to develop their higher-order thinking skills (HOTS), which involve rote memorization and synthesis, analysis, reasoning, comprehension, application, and evaluation of a problem. Lower-order thinking skills (LOTS) can be attained through textbooks and classroom teaching. Problem-based learning, along with a systematic assessment and interaction with peers, is necessary for HOTS.

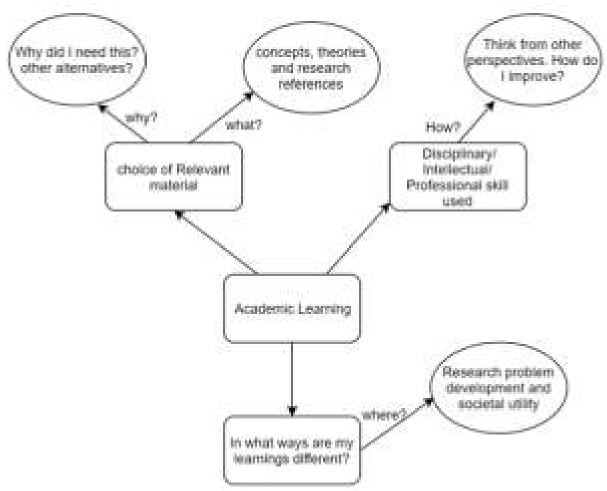

Fig 2: Critical aspects and assessments needed

The DEAL model is one of the successful models among students for transacting from the primary stage to project development (Ash & Clayton, 2009). This model gives the students a critical reflection on the project they are working on. This involves,

D = "Description of experiences in an objective and detailed manner."

E = "examination of those experiences in light of specific learning goals or objectives."

A= Articulation of L= learning - "including goals for future action that can then be taken forward into the next experience for improved practice and further refinement of learning".

This learning method also prompts on the questions that each student answers - What did I learn? How did I learn it? What does it matter? What will I do in light of it? The critical reflections that are assessed to improve all aspects of the graduate outcomes are given in figure 2.

Problem-based learning should improve personal skills, interpersonal skills and team building. So, our work also involves an assessment to improve the behavioral aspects of the students. Thus, with this teaching-learning and assessment, the three graduate outcomes can be acquired, and there can be a notable improvement among the students.

4. Methodology

Our work is divided into conceptualization, course design, and field testing. The Blooms taxonomy levels are also specified in the rubrics wherever applied to ensure that the HOTS are attained.

A. Conceptualization

The students are prepared to solve a problem, design a real-time network with proper configurations, and include IoT devices. Through project-based learning, the students are required to take up the entire design, analysis, and execution of the work as a team, helping them acquire knowledge, skill, and the right attitude.

B. Course Design

This step involves deciding on a skill-based subject on which the students are assessed. The course outcome is also at the HOTS level. The syllabus, outcome, and tool used are as follows. Modern tool usage is also included to ensure that all the POs are considered.

The course taken up for study is "Internet of Things". The topics covered during this experiential learning phase are: Fundamentals of IoT- IoT Reference Architecture-Sensors, Endpoints and Power Systems- IoT Standards and Protocols-MQTT, CoAP, AMQT, STOMP.

Course Outcome: Implement Computation and Communication specifications in the Internet of Things Systems based on application demands (Apply Level).

Tool: Cisco Packet Tracer is identified to simulate the IoT Workspace and support problem-based learning. Students use this tool to design an IoT workspace with network connectivity and computing capability.

Critical Reflections: The use of a modern tool and the problems are given concerning real-time scenarios help the students to

1. Create Curiosity - assimilate new information to resolve the problem
2. Reflective Process Model – Lesson Plan Activity in Moodle
3. Encouraging Lateral Thinking through Assignments

C. Field Testing

Any learning always starts with a Lower-order thinking skill, which involves understanding the basic concepts, remembering specific theories to be used further, and then moving on to Higher-order thinking.

So, a Lesson Plan was organized using external video content followed by questions to assess the LOTS & HOTS level cognitive skills from video lectures.

The overall learning process is elaborated as follows in Figure 3.

The learning management system used is Moodle. This has ways to create course content, post quizzes, get feedback and assess the learners based on created rubrics. The video recordings are posted in Moodle, and the contents are all digitalized to support E-Learning. The students learning from the lectures are asked to prepare a course journal on their understanding of the topics. This is an outclass activity for a flipped classroom strategy.

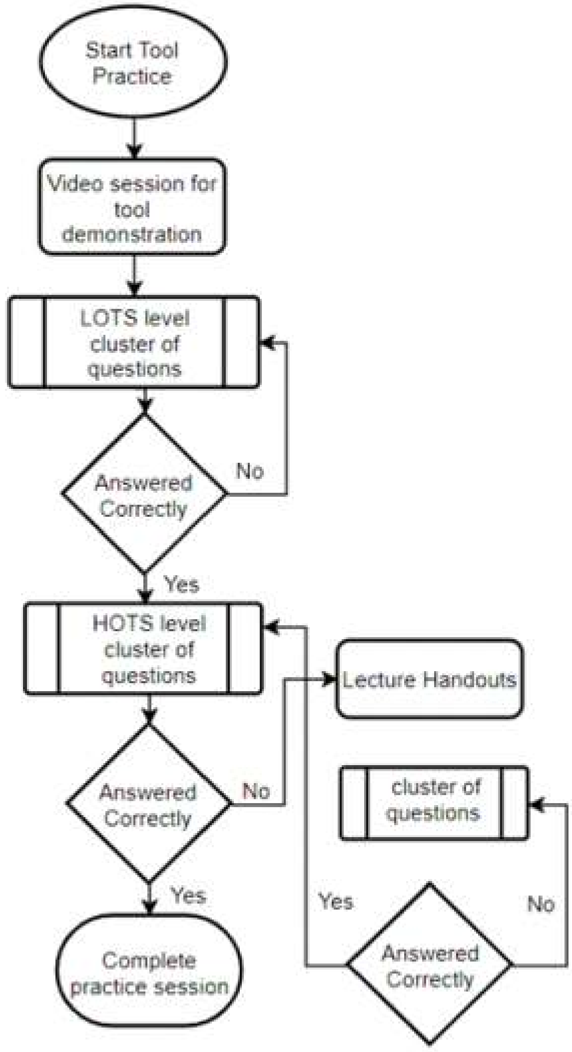

Fig. 3: Learning process

The essential understandings of the concepts are tested via LOTS cluster, and only then do they move on to HOTS assessments. Students who could not perform well in HOTS assessments are given a course handout with smaller experiments, and a change in cognitive skill level may induce better learning. Such a scenario may be due to students' lag in visual and auditory level learning styles; hence, he is offered the Kinematics learning style through lecture handouts.

To better understand the students, assignments are given to them with a well-defined and measurable problem. The students approach the problem based on their experience in problem-solving.

Only the problem is given to them to introduce them to a complex engineering problem. The assessment given to them is shown in figure 4.

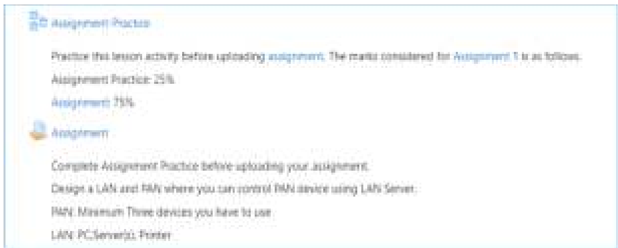

Fig.4: Assessment

Student feedback is a significant evaluation metric of the flipped classroom activity, collected formally and informally. Formal feedback was collected through Google forms/ Moodle feedback forums. Anonymous feedback were also collected in the classroom to know the students' engagement in the Flipped classroom activity. Students were instructed to create the course journal and post it in Moodle discussion forum. The students reviewing others' journals were credited. When they were asked to post it in the discussion forum, plagiarism was reduced, and it is effortless to find the copied content. The students were also able to understand the concept from different perspectives.

5. Results And Discussion

Traditional learning only involves the information transmission, a problem presented by the faculty, and the solution to make them understand the concept. There is no experiential learning here for the students and promotes only LOTS development. In our proposed problem-based learning, along with tool usage, a problem is presented, and the students are given the liberty to analyze, gather information and come up with a solution.

The questions/ problems are framed to facilitate discovery and stimulus for learning through problems. A comparison of the learning levels for OBE and PBL learning is given in Table II.

The problem based learning Approach is achieved through Collaborative Learning. Peer learning is initiated as the learner's responsibility. Team Formation Strategy:

- The groups are carefully chosen as a mixture of students with different learning styles.

Table 2 :
Comparison Of Obe And Pbl Learning Levels

Outcome-Based Education (OBE)	Cognitive Level	Problem Based Learning (PBL)	Cognitive Level
Define the term Things In Internet of Things	Understand	Design a Personal Area Network with at least three devices and justify how devices become things	Apply
Illustrate Networking Capabilities in an IoT Environment	Apply	Design a Local Area Network 1 & Network 2 and experience the network connectivity	Apply
Illustrate the IOT cloud-based service using smart network and discuss the benefits and limitations of wireless sensor networks.	Apply	Design a Logical workspace of Smart Home Automation and create a web application/mobile application to control smart home devices	Apply, Create

- The group members are changed often to minimize group cohesiveness
- The teams are monitored to check the distribution of the work among the entire team member
- The team size is essential to ensure the full participation of members. Hence it is fixed as 3-4 per team

One student in a team is given the additional role as a recorder to record all the discussions and conclude the team problem-solving solution.

There have been works wherein the students' ethical competence during their internship period were assessed (Jiménez et al 2023). This assessment helped improve curriculum design for the undergraduate Industrial Engineering Program.

The motivation towards devising the peer learning strategy is to build a social behavioral classroom atmosphere. Behavior Factor (BF) evaluation is sometimes a long-term process where learners apply their learning and change their behaviors immediately or several months after graduation. The rubrics are mapped with behavioral components such as Self-Assessment (SA), Communication (C), Relationship (R), Trust (T), Responsibility (Re), Optimism (O), Challenge (Ch), Enthusiasm (E), Motivation (M), and Honesty (H). The rubrics devised for the course is elaborated in Table III.

Table 3 : Behavioral Assessment Elements

	Excellent (4)	Very Good (3)	Good (2)	Satisfactory (1)	BF
Team Formation	Comprises of all types of learners i.e., active, slow, notorious, vernacular	Active, slow, and vernacular	Active and vernacular	either active/ slow/ notorious / vernacular	SA, C, R, Ch, E
Team discussion	People working well together with a positive attitude.	More team involvement with less inspiration and often positive attitude	Less involvement and usually positive attitude	Aggressiveness with a negative attitude	C, R, Re, O, E, H
Delivery skill	Correct solution by slow learner/ Notorious/ vernacular	Incorrect solution by slow learner/ Notorious/ vernacular	Correct solution by team leader	Incorrect solution by team leader	SA, C, Re, O, Ch, M

A. Overall Evaluation Process for the course:

The students have to be assessed in all aspects of their graduate outcomes. So, we have developed an evaluation to assess both the individual and team development skills. The individual skills are assessed in two levels, formative and summative as described below. The activities are devices, and the rubrics are designed accordingly for effective valuation.

Formative: interaction/polling with the team members (Score: X, weightage: 20%)

Summative: Quiz Activity using clickers (Score: Y, weightage: 30%)

Similarly, team development skills are assessed at formative and summative levels.

Formative: Interaction during team discussion about problem-solving (Score: Z, weightage: 20%)

Activity: Observing the team involvement and commitment in problem-solving

Summative: Team Presentation (Score: T, weightage: 30%)

Activity: Evaluating recorder report from each team along with their presentation skill.

So, based on these factors, the individual score is calculated as,

Table 4 : Overall Assessment Rubrics

	Excellent (4)	VeryGood (3)	Good (2)	Satisfactory (1)
Team Formation (X)	Comprises of all types of learners i.e, active, slow, notorious, vernacular	Active,slow and vernacular	Active and vernacular	either active/ slow/ notorious/ vernacular
Team discussion (Z)	People working well together with positive attitude	More team involvement with less inspiration and often positive attitude	Less involvement and usually positive attitude	Aggressiveness with negative attitude
Delivery skill (T)	Correct solution by slow learner/ Notorious/ vernacular	Incorrect solution by slow learner/ Notorious/ vernacular	Correct solution by a team leader	Incorrect solution by a team leader

The rubric is carefully knitted and deliberated before knowing each activity's weightage. The assessment rubric is given in Table IV:

6. Conclusion and Future Work

Our study highlights how DEAL model plays a crucial role in how teaching in efficient through Problem-Based Learning . DEAL acts as a guide to help students reflect on what they're learning through Description, Examination, Articulation, and Learning. It encourages students to talk about their experiences, think about them carefully, express what they've learned, and keep learning from them. This combination of DEAL and PBL is like a smart plan that helps students understand theories and learn practical skills, be ethical, and get better at working with others. Given a complex engineering problem, they have identified and formulated the challenges, explored the various solutions, experimented on them, and learned from the experiences. Finally, as a team, the students were able to develop an ethically and technically feasible solution. By working as a team, they gained interpersonal skills and improved their peers' learning. Their higher-order thinking skills were improved, and our proposed rubrics were able to capture the improvements in the learners.

As future work, we would extend this to other skill-based courses and compare the students' behavioral and technical improvements after they were introduced to problem-based learning.

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