Enhancing Student Learning Efficiency Through Project Oriented Problem Based Learning in Renewable Energy Technology Course

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***Abstract*— This paper investigates the transformation of a Renewable Energy Technology (RET) course syllabus via Project Oriented Problem Based Learning (POPBL), aligned with Constructive Alignment principles, to foster a student-centric learning environment. Traditional lecture-based methods often fall short in engaging students in complex subjects like renewable energy, prompting a shift towards PBL, emphasizing active learning and real-world problem-solving. The redesigning of the course involves mapping course objectives and core concepts to project themes and assignments, ensuring alignment between learning outcomes, assessments, and student activities. Integration of simulation models into project development offers hands-on experience in designing of the RET course. Post-implementation observations indicate that this approach significantly enhances problem-solving skills and fosters a deeper understanding of the subject matter, evidenced by the development of simulation-based projects. Therefore, the redesigning course syllabus empowers students to explore and apply renewable energy concepts practically, preparing them for future careers in the field and promoting innovation in renewable energy education.**

***Keywords*— Constructive alignment; Engineering education; Project based learning; Renewable energy technology; Simulation software.**

I. INTRODUCTION

Problem based learning (PBL) is an innovative approach to inquiry-based learning that focuses on the key concepts and principles of a subject. It involves using a variety of resources and engaging in continuous inquiry-based activities in real-world contexts. The goal is to complete a comprehensive project that addresses multiple related issues within a set timeframe Zhang, L. & Ma, Y. (2023). A practical solution to tackle this issue is to adopt project-oriented problem-based learning (POPBL) Poli, L. R. & Narendar, S. D. (2024) and it is highlighted that POPBL emphasizes experiential education, which goes beyond basic hands-on activities by engaging students in learning through doing. This approach offers valuable insights for student learning by integrating theory and practice, thereby fostering a motivation to learn. In this model, the teacher acts as a facilitator of the learning process rather than merely a provider of knowledge. It encourages students to take charge of their learning journey, creating a more student-centred classroom environment. Teachers, in turn, become facilitators who guide the learning process alongside delivering subject content.

Problem-based learning enhances critical thinking skills, problem-solving abilities, creativity, teamwork, and student engagement in learning. It promotes collaboration, decision-making, social-emotional learning, personalized learning, and a multi-stage analysis of the problem at hand. This approach deepens students' understanding of concepts, encouraging self-directed learning that enables them to apply acquired knowledge to real-world problems. It helps students develop flexible knowledge and intrinsic motivation, allowing them to learn concepts rather than merely absorbing facts, thereby improving their analytical skills Elaine, H. J. Y. & Karen G. (2016).

The constructive alignment (CA) framework is a valuable tool for enhancing student learning efficiency in a renewable energy technology (RET) course through POPBL. This framework ensures that the learning outcomes, teaching methods, and assessment tasks are coherently aligned, creating a structured and purposeful educational experience Stamov R. C., L. B. K. & Fitzallen, N. (2021). In the context of the RET course, the framework can guide the design of POPBL activities that are directly linked to the desired skills and knowledge students should acquire, such as critical thinking, problem-solving, and practical application of renewable energy concepts. By clearly defining these outcomes and aligning them with hands-on projects, the framework helps students to understand the relevance and application of theoretical knowledge in real-world scenarios Iqbal, A. R. & Nadi, S. (2024). Additionally, CA stresses the importance of aligning formative assessment to other parts of curriculum that provide ongoing feedback, enabling students to reflect on their learning process and make continuous improvements. This alignment of objectives, activities, and assessments not only enhances student engagement and motivation but also fosters a deeper understanding of the subject matter, thereby improving overall learning efficiency and the concept of this system is shown in Fig. 1 and describes that the framework ensures that course activities and assessments align with the desired learning outcomes. It emphasizes designing appropriate activities for students to acquire competencies, using assessments to demonstrate their proficiency, and ensuring that these components support each other to achieve the course's educational goals.

Project oriented problem-based learning (POPBL) can greatly enhance student learning outcomes, including academic performance, motivation, and higher-order thinking skills. In Karpudewan, M. Ponniah, J. & Zain, A. N. M. (2016) studied the effectiveness of PBL in improving energy literacy among secondary school students.

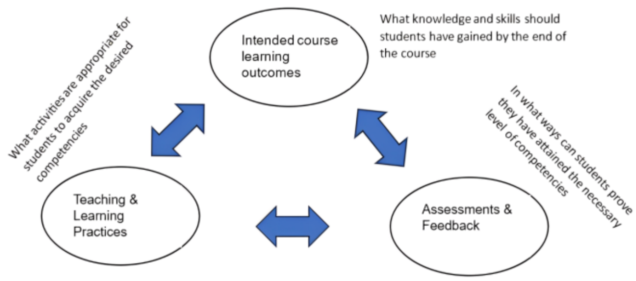

Fig.1. Constructive Alignment Framework

The study's quantitative results revealed that students exposed to a PBL curriculum demonstrated better knowledge, attitudes, behaviours, and beliefs related to energy compared to those taught through traditional methods. In Biazus, M. & Mahtari, S. (2022) conducted a quasi-experiment comparing PBL and direct instruction models. They found that PBL significantly improved the creative thinking skills of secondary school students. In Biggs, J. & Tang, C. (2011), described constructive alignment as the coherence between intended learning outcomes (ILOs), learning and teaching activities (LTAs), and assessment tasks (ATs) in an educational program. This alignment is based on the learning activities outlined in the outcome statements. The framework optimizes learning conditions by ensuring that both the teacher's teaching activities and the student's learning activities are focused on the same goal. In Chernikova, O (2020), explained that the meta-analysis shows that simulation-based learning significantly improves complex skill development in higher education, with an effect size of g = 0.85. Different scaffolding methods, such as reflection for advanced learners and examples for beginners, enhance learning outcomes. The study confirms the robust effectiveness of simulations across various domains, highlighting the importance of tailored support and technology integration. In Du, X.Y. & Lundberg, A. (2021), highlighted that PBL, also known as learning via projects, is widely seen as an effective teaching method. It focuses on learner-centred education and is guided by the principle of learning by doing, which enhances critical thinking, problem-solving skills, teamwork, cooperative learning, and commitment to achieving goals. PBL and POPBL can improve students' learning capacities through engaging and comprehensive projects. In the current educational landscape, problem-solving topics such as renewable energy technology—especially solar and wind power generation—present significant research opportunities and practical applications. Implementing Problem-Based Learning (PBL) and Project Oriented Problem Based Learning (POPBL) approaches can offer students invaluable hands-on experience, crucial for understanding and solving complex issues related to renewable energy systems. These methods enable students to engage deeply with real-world problems, apply theoretical concepts to practical scenarios, and develop innovative solutions. This paper aims to demonstrate how POPBL not only foster experiential learning but also enhance student outcomes by effectively aligning course objectives, teaching strategies, and assessment techniques. By integrating these elements within the framework of renewable energy technology, students gain a comprehensive and cohesive learning experience that better prepares them for future challenges in the field. The RET course is available in the third year of the four-year undergraduate program to the Electrical and Electronics Engineering department students at Anurag University. This 3-credit course offers an in-depth exploration of various renewable energy sources, including their power generation processes, performance characteristics, and potential in India. It also covers solar photovoltaic systems, applications of diverse renewable energy technologies, and different wind power system topologies.

The following highlights the challenges and problems related to the existing RET course.

1. The syllabus primarily addresses fundamental concepts related to various renewable energy sources.
2. It does not adequately address the solutions to challenges faced by the current renewable energy industry.
3. Incorporating real world issues to illustrate theoretical principles is essential.
4. The extensive scope of the syllabus, covering a broad range of topics such as solar, wind, geothermal, and bioenergy, may overwhelm students and hinder their ability to achieve a deep understanding of each area.
5. Although the syllabus includes theoretical concepts, there may be insufficient opportunities for hands-on experience with real-world applications and systems.

II. Redesigning the RET course based on POPBL

The research involved redesigning the RET course using POPBL and Constructive Alignment to foster a student-centered learning environment. It aligned course objectives with project themes and incorporated simulation-based activities. The research questions explored how this alignment could improve engagement and practical understanding. The following modifications will be implemented in different phases:

A. *Constructive Alignment Framework*

The updated syllabus will include concepts that are more suitable for implementation through simulation studies or prototyping using hardware components. This approach aims to (Powers, T., & Kirkpatrick, J. (2012).

- Bridge the gap between theory and practice through reflective learning.
- Simulation studies will present numerous problems to the students; eventually, they will learn more by doing.
- Learning through simulation studies and prototyping will speed up the learning process.
- Experiential learning results in demonstrable changes in mindset.
- The student benefits from the high emphasis on teamwork and learning from one another as it raises engagement. On the other hand, because they are directly involved in the problem-solving activity or event, participants have a high amount of ownership over the results.
- To collaborate with others in a group setting to enhance learning.
- Due to their active participation in the problem-solving activity or event, individuals will have a strong sense of ownership over the results.

The course learning outcomes and teaching-learning activities, are all thoroughly aligned and mapped out and shown in Table 1.

The Table 1 outlines the learning outcomes, teaching and learning activities, and assessments for a renewable energy course redesigned with PBL pedagogy. Students will first acquire knowledge of various renewable energy sources through direct classroom teaching. They will then apply this knowledge to solar photovoltaic systems using MATLAB simulations. The course will also cover Maximum Power Point Tracking (MPPT) algorithms, utilizing simulation studies and industrial visits. Additionally, students will learn to identify different types of wind turbines. Finally, the course includes designing a wind energy conversion system integrated with a photovoltaic system, using both simulations and prototype models.

TABLE I
CONSTRUCTIVE ALIGNMENT FRAMEWORK

S.No.	Learning Outcomes	Teaching and learning Activity
CO 1	Acquire knowledge of different types of renewable energy sources.	Direct class room teaching
CO 2	Apply knowledge of solar photovoltaic systems and their operating principles to solar energy conversion technologies.	• Simulation studies using MATLAB • Direct class room teaching
CO 3	Apply the suitable MPPT Algorithms for different types of photovoltaic power generation systems.	• Simulation studies using MATLAB • Direct class room teaching • Industrial visit
CO 4	Identify the different types of wind turbines for respective wind power generating system.	• Direct class room teaching • PPTs, Video lectures
CO 5	Design a wind energy conversion system and integrate it with a photovoltaic power generation system.	• Simulation studies using MATLAB. • Prototype models • Direct class room teaching

B. Course Assessment

The course assessment mainly divided into two parts i) continuous internal evolution (CIE) ii) semester end evaluation (SEE). The complete details of the weightage of the marks for both CIE and SEE and the other details mentioned in Table 2.

TABLE II
COURSE ASSESSMENT

Assessment 100 Marks				
CIE (60 Marks)				SEE (40 Marks)
CO's	**Assessment method**	**Marks**	**Total Marks**	**SEE Pattern**
CO1	Poster presentation-I	**10**	**10**	SEE is a completely closed book examination that will be held for 40 marks.
CO2	Analytic memo	**10**	**10**	
CO4	Poster Presentation-II	**10**	**10**	
CO3	Simulation Model Presentation	**30**	**Average of CO3 & CO5 (30)**	SEC-A: 10 Marks (1X10 = 10 Marks)
CO5	Simulation Model Presentation	**30**		SEC- B: 30Marks (5X6=30 Marks)
Total			**60 Marks**	**40 Marks**

From Table 2, it is understood that the CIE, worth 60 marks, includes several activities:

• **CO 1 - Poster presentation-I:** The students need to prepare a poster centered on the first unit of study. The poster focused on elucidating various renewable and non-renewable energy sources, along with providing statistical data pertaining to renewable energy sources.

• **CO 2 - Analytic memo:** The analytic memo is a simulation exercise. The students need to write a two pages report which consists of brief analysis of a specific problem going to develop a simulation model involving different solar energy conversion technologies and their applications.

• **CO 3 - Simulation Model Presentation-I:** The students need to develop simulation sub-model for solar power plant and analyze its behavior for various loading conditions.

• **CO 4-Poster Presentation-II:** The students need to prepare a technical poster on wind turbines and corresponding classifications on the basics of design and application.

• **CO5 - Simulation Model Presentation-II:** The students required to integrate the basics of MATLAB sub-models of solar and wind and develop a complete wind- solar hybrid energy system for uninterrupted power supply in grid connected/islanding mode.

The semester end evaluation (SEE) consists of 5 essay questions and there is individual choice for each, students need to attempt all the five questions and the same is evaluated for 30 marks. Short answer consists of 10 questions and student need to attempt all the 10 questions and the marks allotted to each question is 1 mark in 180 minutes. Student should get 40 % of the total SEE to qualify for the exam.

C. Design and development of simulation model

The design and development of simulation-based model will be consisting of three stages and are given in the Fig. 2, and explained is as follows:

1) **Stage 1:** Initially students will be divided into different batches (Three students in each batch). Each student group within their respective batches identify a particular problem within the domains of i) stand-alone solar power generation systems, ii) grid integration of solar power, and iii) solar shading. Subsequently, they conducted thorough calculations pertaining to load requirements, solar power generation capacity, and the constituent components involved in the generation process. Each group prepared a comprehensive report addressing their specific problem and submitted it within the specified timeframe. If the report is able to explain the problem clearly and the process students go through the stage 2.

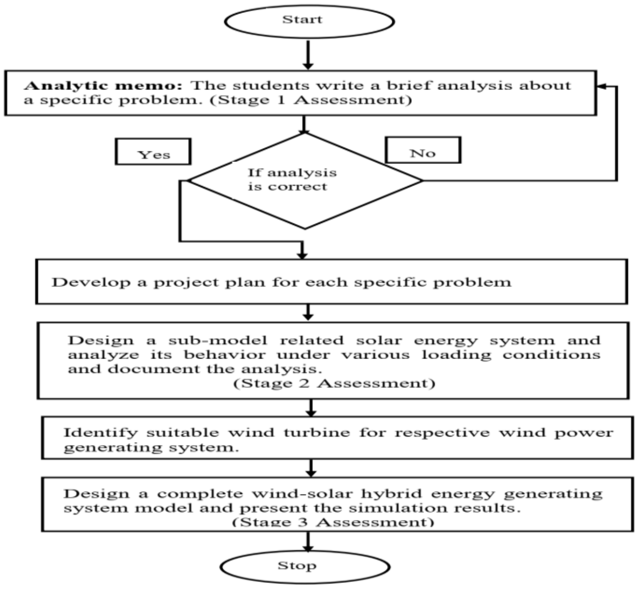

Fig. 2. Flowchart of design and development of simulation model.

2) **Stage 2:** In response to Analytic memo, each student batch craft a simulation model specifically tailored to the problem they had selected. They diligently tackle challenges related to the integration of solar power into the grid and standalone systems, gaining a deep understanding of these issues. Subsequently, they conduct a thorough analysis of the simulation results and compiled comprehensive reports that detailed their findings and insights.

3) **Stage 3:** Students need to identify the suitable wind turbine for respective wind power generation system. Then design and develop a wind model for chosen wind power generating system and combined with solar model finally developed hybrid solar-wind model and analyze the obtained results and compiled comprehensive reports that detailed their findings and insights.

D. Rubrics for Assessment evaluation

The rubrics for all the assessment activities are given in Table 3-7 respectively. The revamped RET course encourages students to take charge of their education by identifying specific areas within the subject that need further exploration. Students pinpoint these gaps, conduct thorough research, and implement their understanding to devise practical solutions, which they submit as reports for assessment. The course's goals, teaching strategies, and evaluations are cohesively structured to boost problem-solving skills. This redesign focuses on experiential learning through problem-based and project-based approaches, enabling students to apply theoretical concepts to practical issues in renewable energy technologies, such as solar and wind energy systems.

TABLE III
RUBRICS FOR POSTER PRESENTATION - I OF CO 1

Criteria	Excellent	Good	Needs improvement
Design of the poster (3 M)	Excellent visual presentation and design, well-organized, visually appealing, and effectively uses graphics to enhance understanding of the concepts. **(3 M)**	Adequate visual presentation and design. coherence evident, with moderate use of graphics to help understand the concepts. **(2 M)**	Inadequate visual presentation and design. Poor organization, lack of coherence, and minimal use of graphics to understanding of the concepts. **(1 M)**
Understanding for Content knowledge (4 M)	Thorough understanding of renewable energy sources and their basics. Accurate and comprehensive information is presented with clarity and coherence. **(4 M)**	Adequate understanding of renewable energy sources and their basics. Some accurate information is presented. **(2 M)**	Limited understanding of renewable energy sources and their basics. Incomplete information is presented. **(1 M)**
Viva (3 M)	Accurate and thorough responses to questions, demonstrating a high level of expertise. **(3 M)**	Some accurate responses to questions. **(2 M)**	Incomplete responses to questions. **(1 M)**

TABLE IV
RUBRICS FOR ANALYTIC MEMO OF CO 2

Criteria	Excellent	Good	Needs improvement
Understanding of the specific problem4 Marks)	In-depth understanding of the specific problem. Analysis, showcases comprehensive knowledge, critical insights, connections to relevant concepts and theories related to different solar energy conversion technologies and their applications. **(4 M)**	Adequate understanding of the specific problem. Analysis, demonstrates basic knowledge and comprehension of solar energy conversion technologies and their applications. **(3 M)**	Limited understanding of the specific issue on different solar energy conversion technologies and their applications. **(2 M)**
Analysis and evaluation (4 Marks)	Rigorous analysis and evaluation of the specific problem. Shows thorough critical thinking, systematic evaluation, and insightful analysis of different solar energy conversion technologies. **(4 M)**	Adequate analysis and evaluation of the specific problem. Demonstrates some critical thinking and evaluation of different solar energy conversion technologies. **(3 M)**	Limited analysis and evaluation of the specific problem. Superficial examination of the topic with minimal evaluation of different solar energy conversion technologies. **(2 M)**
Submission of Synopsis (2 Marks)	In time submission **(2 M)**	Late submission **(1 M)**	Not submitted **(0 M)**

TABLE V
RUBRICS FOR SIMULATION MODEL PRESENTATION – I OF CO 3

Criteria	Excellent	Good	Needs improvement
Model Development (10 M)	Excellent development of the simulation sub-model for the solar power plant. The model accurately represents the key components, behaviors, and interactions within the solar power plant. **(10 M)**	Satisfactory development of the simulation sub-model for the solar power plant. The model includes most necessary components, but there may be minor errors and areas for improvement. **(6 M)**	Inadequate development of the simulation sub-model for the solar power plant. The model lacks essential components, may contain significant errors and inconsistencies. **(4 M)**
Analysis of Behavior (5 M)	Thorough analysis of the behavior of the simulation sub-model for various loading conditions. Shows a comprehensive understanding of the outputs, identifies significant results. **(5 M)**	Adequate analysis of the behavior of the simulation sub-model for various loading conditions. Demonstrates an understanding of the outputs and identifies some significant results. **(3 M)**	Limited analysis of the behavior of the simulation sub-model for various loading conditions. Incomplete examination of the outputs. **(2 M)**
Accuracy and Reliability (5 M)	Highly accurate and reliable simulation results and interpretations. The model outputs closely match the expected behavior, and the simulation is robust, providing a high level of confidence in the accuracy and reliability of the results. **(5 M)**	Moderately accurate and reliable simulation results and interpretations. The model outputs generally align with the expected behavior, but there may be minor deviations or limitations in the accuracy or reliability of the simulation. **(3 M)**	Inaccurate simulation results and interpretations. The model outputs do not align with the expected behavior or there are significant discrepancies between the simulation and real-world observations. **(2 M)**
Presentation and Communication (5 M)	Excellent presentation of the simulation model and its analysis, and presents the information clearly and effectively. **(5 M)**	Adequate presentation of the simulation model and its analysis. Presents the information with some clarity. **(3 M)**	Poor presentation of the simulation model and its analysis. Lack of clarity, in conveying the information. **(2 M)**
Report (5 M)	Excellent introduction and background information, a description of the methodology and approach used, and thorough findings and analysis on solar energy conversion technology with strong conclusions and valuable recommendations. **(5 M)**	Satisfactory introduction, background information, description of the methodology, approach used, and adequate findings and analysis on solar energy conversion technology with adequate conclusions and recommendations. **(3 M)**	Inadequate introduction, background information, description of the methodology, approach used, and limited findings and analysis on solar energy conversion technology with weak conclusions and limited recommendations. **(2 M)**

TABLE V
RUBRICS FOR POSTER PRESENTATION - II OF CO 4

Criteria	Excellent	Good	Needs improvement
Design of the poster (3 M)	Excellent visual presentation and design. Well-organized, visually appealing, and effectively uses graphics to enhance understanding of the concepts**.** **(3 M)**	Adequate visual presentation and design. Moderate use of visual elements to understand the concepts. **(2 M)**	Inadequate visual presentation and design. Minimal use of visual elements to understand the concepts. **(1 M)**
Content Knowledge and Understanding (4 M)	Thorough understanding of wind turbines, their classifications, and basics of design and applications. Accurate and comprehensive information presented with clarity. **(4 M)**	Adequate understanding of wind turbines, their classifications, and basics of design and applications. Some accurate information presented. **(2 M)**	Limited understanding of wind turbines, their classifications, and basics of design and applications. Incomplete information presented. **(1 M)**
Viva (3 M)	Accurate and thorough responses to questions, demonstrating a high level of expertise. **(3 M)**	Some accurate responses to questions. **(2 M)**	Incomplete responses to questions. **(1 M)**

TABLE VII
RUBRICS FOR SIMULATION MODEL PRESENTATION - II OF CO 5

Criteria	Excellent	Good	Needs improvement
Hybrid Model Development (10 M)	Excellent integration of MATLAB sub-models for the wind and solar hybrid energy systems. The integration accurately represents the key components, behaviors, and interactions within the hybrid energy system. **(10 M)**	Satisfactory integration of MATLAB sub-models for the wind and solar hybrid energy systems. The integration includes most necessary components, but there may be minor errors. **(6 M)**	Inadequate integration of MATLAB sub-models for the wind and solar hybrid energy systems. The integration lacks essential components and may contain significant errors. **(3 M)**
Analysis of model behavior (5 M)	Thorough analysis of the system behavior for the wind and solar hybrid energy systems. Shows a comprehensive understanding of the outputs, and provides insightful interpretations and explanations. **(5 M)**	Adequate analysis of the system behavior for the wind and solar hybrid energy systems. Demonstrates an understanding of the outputs and identifies some significant results. **(3 M)**	Limited analysis of the system behavior for the wind and solar hybrid energy systems. Incomplete examination of the outputs and limited understanding of the observed results. **(2 M)**
Accuracy and Reliability (5 M)	Highly accurate and reliable simulation results. The model outputs closely match the expected behavior, and the simulation is robust, providing a high level of confidence in the accuracy and reliability of the results. **(5 M)**	Moderately accurate and reliable simulation results and interpretations. The model outputs generally align with the expected behavior, but there may be minor deviations or limitations in the accuracy or reliability of the simulation. **(3 M)**	Inaccurate or unreliable simulation results and interpretations. The model outputs do not align with the expected behavior. **(2 M)**

Presentation and Communication (5 M)	Excellent presentation of the simulation model and its analysis. Presents the information clearly and effectively. **(5 M)**	Adequate presentation of the simulation model and its analysis. Presents the information with some clarity. **(3 M)**	Poor presentation of the simulation model and its analysis. Lack of clarity, in conveying the information. **(2 M)**
Report (5 Marks)	Excellent introduction and background information, a description of the methodology and approach used, and thorough findings and analysis on solar and hybrid wind development with strong conclusions and valuable recommendations. **(5 M)**	Satisfactory introduction, background information, description of the methodology, approach used, and adequate findings and analysis on solar and hybrid wind development with adequate conclusions and recommendations. **(3 M)**	Inadequate introduction, background information, description of the methodology, approach used, and limited findings and analysis on solar and hybrid wind development with weak conclusions and limited recommendations. **(2 M)**

III. Results and Discussion

The adoption of POPBL comes with various challenges, such as handling large student groups, limited time for individualized assessment, guidance, and students' insufficient foundational knowledge and coding abilities. During the implementation phase, several positive outcomes were observed, POPBL empowered students to use simulation tools in real-world applications, actively engaging them through hands-on activities, experiments, and projects, which significantly enhanced experiential learning. This approach also improved teamwork and collaboration, bolstered presentation and report-writing skills, and helped students grasp the importance of each subject while recognizing the interconnectedness between various disciplines. Performance of 112 students about poster presentation-I and II analysis are depicted in Fig. 3 & 4 respectively, from these results it is understood that there is a great improvement in the student performance in understanding content knowledge and able to give the answers pose by the evaluator. Regarding, Analytic memo, students have identified the problem related to hybrid power system and the problem is solved by using simulation-based approach. Similarly, the simulation-based assessment test analysis for assessment III & V is depicted in Fig. 5 & 6 respectively. From these figures it is concluded that there is a great enhance in designing simulation model and able to explain the results effectively. The redesign Philosophy of the RET course is given in Table 8. From this table it is understood that the redesign syllabus is mostly concentrated on develop a project, various assessments instead of closed book examinations. The feedback taken from the students for some of the questions is shown in Fig 7. From this, it is understood that the students have improved their skills in different environments and majority of the students agreed to learn the concepts with PBL/POPBL.

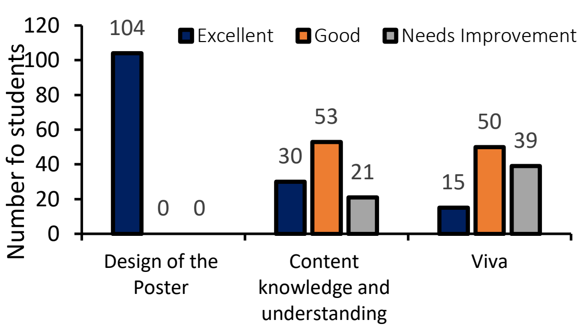

Fig. 3. Analysis of Poster Presentation-I

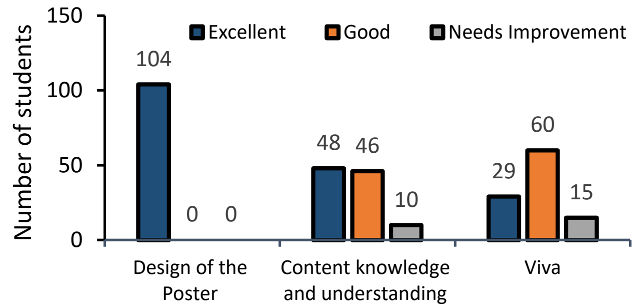

Fig. 4. Analysis of Poster Presentation-IV

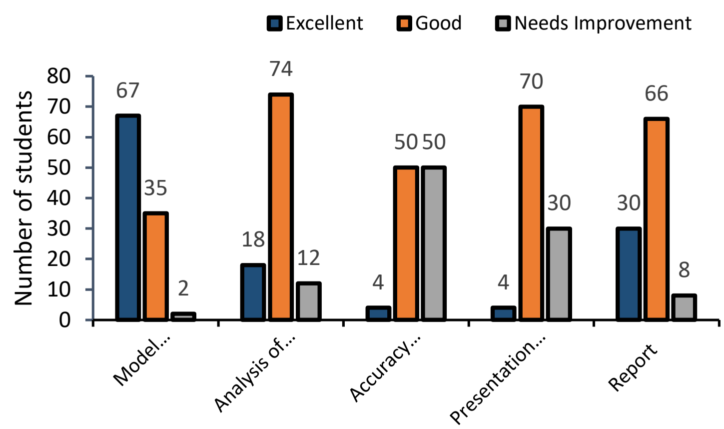

Fig. 5. Analysis of Simulation Model presentation-I

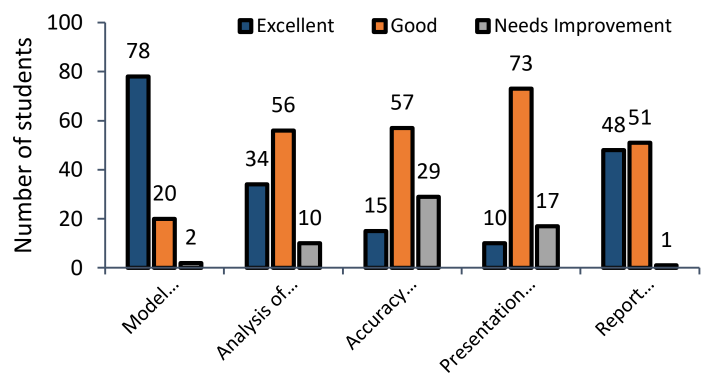

Fig. 6. Analysis of Simulation Model presentation-II

TABLE. VIII
REDESIGNING PHILOSOPHY

Parameter	Before	After
Course Structure	Theory	Theory and VAC
Syllabus	Introduction Level of all type of renewable energy sources	Concept clusters related to specific renewable energy sources
Assignment/Project	Two Assignments out of 5 units	Project Starts from II Unit
Assessments	Summative: Descriptive exam (Closed book examination)	Summative, Poster Presentation I, Analytic memo, Presentation on simulation model, Poster Presentation II,

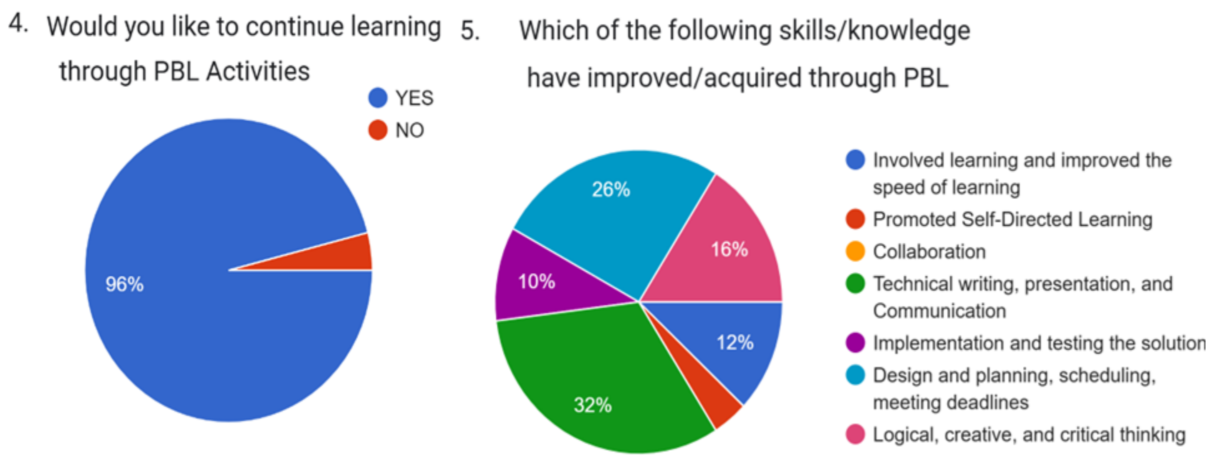

Fig. 7. Analysis of feedback taken from the students

CONCLUSION

This paper outlines a course-level framework for Problem oriented Project-Based Learning (POPBL), emphasizing experiential learning within the Renewable Energy Technology curriculum, specifically focusing on solar and wind power generation. The framework is structured to evaluate students using rubrics that align with clearly defined learning outcomes. Through this approach, students are guided through a systematic, phased process to tackle real-world renewable energy challenges, such as grid connected solar PV systems and wind power generation. This educational strategy equips students with practical skills and knowledge, facilitated by the use of simulation tools, and promotes critical thinking, self-directed learning, and advanced cognitive skills. POPBL offers students practical, project-oriented learning experiences, enabling them to effectively understand and solve problems associated with solar and wind energy technologies, thus serving as a valuable active learning pedagogy.

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