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Adoption of Experiential Learning Approach for Validation of Perpetual Motion Machine of First Kind Concept in Engineering Thermodynamics

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Abstract— **Educationalists among the globe are innovating and experimenting innovative teaching practices to the students to trigger students involvement, grasp of the concepts and performance. Engaging students in practical and challenging activities is one of the way to engage students in the learning process. The learning through inference drawn from these activities and experience is referred as an experiential learning. Experiential learning has evolved as a superior teaching-learning methodology over conventional classroom teaching. Autonomy in learning to the students and triggering creative thinking in students are the key aspects of experiential learning methodology. Educationalists have adopted experiential learning to science and technology, medical, management and engineering disciplines and is being more popular day by day. This article presents experiential learning model applied to engineering thermodynamics course (subject) for validation of basic thermodynamic concepts. Student validated working of a machine without any work input by reproducing the machine claimed in the videos uploaded on video sharing platforms. Flexible learning system helped students to have proper understanding of basic concepts, laws of thermodynamics and understanding and to improve academic performance. The activity conducted resulted in the improvement in the overall CO attainment by 14.12% along with improvement in the average marks of the students for UT1, UT2 and ESE assessment collectively by more than 55%.**

Keywords— **Experiential learning; learning by doing; engineering thermodynamics; flexible learning framework.**

I. INTRODUCTION

EXPERIENTIAL learning is an active learning strategy that involves learning through experience gained through activities like experiments, field observations, hands on experience etc. It enables students to learn by doing by their own. It helps students, trainee and learners to inculcate new set of skills, viewpoint by involving in an experiential task and analysis and synthesis about the experience. The critical analysis and synthesis, initiative and decision making opportunities for students, becoming accountable, intellectual, social and physical involvement of students and learning opportunities to students are key elements of experiential learning.

It is evident that the conventional classroom teaching-learning involving 'chalk and talk' approach proves unproductive for science and engineering education (Freeman et al., 2014; Waldrop, 2015). In order to improve students learning, active learning techniques like group problem solving and demonstrative examples have become essential part of classroom teaching (Kober, 2015). In addition to this, active learning approaches like 'peer learning' and 'think-pair-share' are becoming more popular amongst educationalist in recent year to improve learning of students (Lom, 2012). Learning experience in science and technology can be enhanced by including hands on exercises like laboratory session (Freeman et al., 2014). At present, many laboratory exercises have fixed learning framework with fixed set of instructions (Handelsman et. al., 2004). By implementing creative and flexible learning framework that gives more learning freedom to students, considerable utilization of practical sessions can be done (Handelsman et. al., 2004).

Inference drawn from the research carried out in a Spanish business school shows that adopting experiential learning activities helps students' grasp of theoretical concepts and improves academic performance (Rodriguez and Morant, 2019). Patil and Meena implemented experiential learning to computer engineering undergraduate students at a private engineering college in India (Patil and Meena, 2018). Powar and Patil employed 3D printing as a learning tool for undergraduate mechanical engineering students developed a technology-enhanced project based learning (TEPBL) model (Powar and Patil, 2022). It was found that utilizing experiential learning activities enhances the employability of engineering students (Patil and Meena, 2018). Gadola and Chindamo presented a case study of Motostudent event, Europe and Formula SAE competition (Gadola and Chindamo, 2017). It was concluded that, engineering student competitions involves students in experiential learning to an open-ended multidisciplinary problem and triggers students' creativity and innovation (Gadola and Chindamo, 2017).

Engineering thermodynamics course is a part of undergraduate mechanical engineering programme at Rajarambapu Institute of Technology (RIT), Rajaramnagar, India. Course content of engineering thermodynamics includes basic thermodynamic concepts like system, boundary, surroundings, first and second law of thermodynamics, entropy, exergy, properties of gases and properties of steam. The perpetual motion machine of kind 1 (PMM1) is the device that violates first law of thermodynamics. In practice, there is no PMM1 exists in the world. However, there are certain videos uploaded on the online video sharing platform like You Tube that claims existence of PMM1 through demonstration. The present work focusses on validation of PMM1 and hence laws of thermodynamics through experiential learning model.

II. METHODOLOGY

The experiential learning activity was planned for undergraduate second year mechanical engineering students. The class division was consisting of total 74 students. Figure 1 shows the methodology adopted for conducting the proposed experiential learning activity.

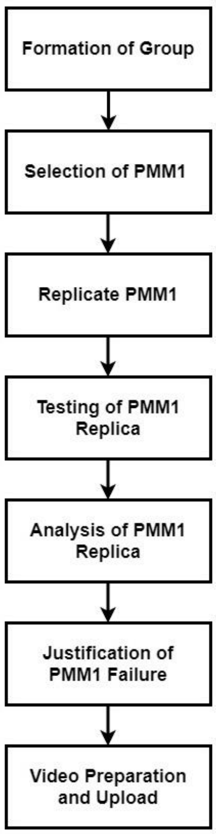


Fig. 1. Methodology Adopted for Experiential Learning

A. Formation of Group

The class of the 74 students was divided into 10 groups with group size of 7-8 students. The group are formed as per mixture of grades/marks of the students. It is ensured that each group have AA to CD grade students. Table I depicts grade system employed in RIT.

TABLE I
STUDENT GRADE SYSTEM (AA TO CD)

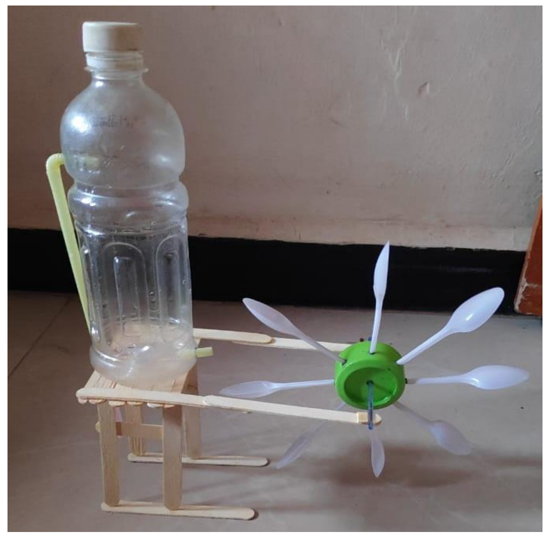
Marks out of 100	<=90	80-89	70-79	60-69	50-59	40-49
Grade	AA	AB	BB	BC	CC	CD

B. Selection of PMM1

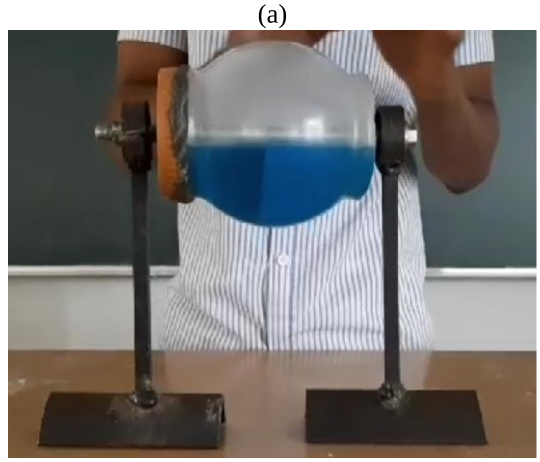
In this phase, different claims of working PMM1 available on online video sharing platform were explored by the students. To remove fixed framework of learning, an autonomy was provided to students to select PMM1 model to replicate. The selected models were finalized for replication after confirmation by course teacher.

C. Replicate PMM1

Finalized PMM1 model was then replicated by the each student group. Observation of video, preparation of list of required tools/devices/instruments required to build the PMM1 model, collection of tools/devices as per the list and fabrication of selected PMM1 model was done by students during replication. Photographs of PMM1 replica fabricated by students is depicted in figure 2 as an illustrative example.



(a)



(b)

Fig. 2. (a) and (b) Pictorial View of PMM1 Replica

D. Testing of PMM1 Replica

Testing of PMM1 replica was conducted by students to validate claim of PMM1. Through testing, students confirmed that no working device can be produced that violates first law of thermodynamics.

E. Analysis of PMM1 Replica

After testing, students analysed PMM1 model critically. This analysis helped students learn through flexible learning framework.

F. Justification of PMM1 Failure

A report was prepared by students that revealed reason for failure of PMM1 model during testing.

G. Video Preparation and Upload

A detailed video was prepared by students incorporating constructional details of model, testing of model and justification of failure. These videos were uploaded on online learning management platform called MOODLE.

For each phase in this activity, a time deadline was set to each group as presented in the table II. Uploaded video on MOODLE was then reviewed by course instructor and evaluation of each group was done. This activity offers flexible learning framework and helps students to be creative and analytical utilizing full potential of practical sessions.

TABLE II
TOPIC WISE COURSE CONTENT

Chapter Number	Activity	Allotted Time (h)
1	Formation of Group	48
2	Selection of PMM1	72
3	Replicate PMM1	96
4	Testing of PMM1 Replica	48
5	Analysis of PMM1 Replica	48
6	Video Preparation and Upload	72

III. COURSE STURUCTURE OF ENGINEERING THERMODYNAMICS

RIT is an autonomous institute and have adopted outcome based education (OBE) system. Implementation of OBE corroborates that students are well competent with the students at national/international level (Terrang et. al. 2015).

Table III demonstrates topic wise course content of Engineering Thermodynamics course along with weightage for evaluation. The course content involves basic concepts of thermodynamics. In order to have better grasp of thermodynamic concepts like entropy and availability, proper perception of laws of thermodynamics is very crucial. Thus, proper comprehension of laws of thermodynamics ensures good grasp of entropy and availability concepts which is content for chapter 2 and 3.

TABLE III
TOPIC WISE COURSE CONTENT

Chapter Number	Title	Weightage
1	Basic Concepts and First Law of Thermodynamics	0.167
2	Second Law of Thermodynamics and Entropy	0.167
3	Availability	0.167
4	Properties of Gases and Gas Mixtures	0.167
5	Properties of Pure Substances	0.167
6	Air and Vapour Power Cycles	0.167

Table IV depicts list of COs defined for the Engineering Thermodynamics course. The COs are defined in such a way that, each CO is mapped with respective chapter.

TABLE IV
LIST OF COs FOR ENGINEERING THERMODYNAMICS COURSE

CO Code	CO Statement
CO1	Apply thermodynamics principles to mechanical engineering applications
CO2	Describe entropy, change in entropy and increase of entropy principle
CO3	Differentiate between available and unavailable energy with examples
CO4	Recognize the properties of pure substances and use thermodynamic property tables, charts
CO5	Apply mathematical fundamental to study the properties of steam gas and gas mixtures
CO6	Explain the air and vapour power cycles and calculate cycle performance

The proposed experiential learning activity which includes validation of PMM1, is intended to have well cognizance of first law of thermodynamics to students. This in turn will improve comprehension of entropy and availability concepts.

TABLE V
MODE OF EVALUATION WITH WEIGHTAGE

Evaluation	Mode of Conduct	Marks	Weightage	Course Content with Weightage
ISE	Online quiz, experiential learning activity	20	0.2	All chapters
UT1	Written Test	25	0.15	Chapter 1 (0.5), Chapter 2 (0.5)
UT2	Written Test	25	0.15	Chapter 3 (0.5), Chapter 4 (0.5)
ESE	Written Test	50	0.5	Chapter 1 to 4 (0.15 each), Chapter 5 to 6 (0.2 each)

The evaluation system in RIT involves in-semester examination (ISE), unit test 1 (UT1), unit test 2 (UT2) and end semester examination (ESE) for every course. Table V shows modes of evaluation scheme, mode of conduct with weightage and course content for Engineering Thermodynamics. The discussed experiential learning activity is conducted as a part of ISE evaluation while UT1, UT2 and ESE is conducted through written test.

The experiential learning activity was performed as a part of ISE evaluation for the engineering thermodynamics course. The evaluation of this activity based ISE was based on a four-criterion rubrics comprising of five scale grading as represented in Table VI.

TABLE VI
EVALUAITON RUBRICS

Criteria	Proficient (4 to 5)	Adequate (2 to 3)	Substandard (0 to 1)
Active Involvement	The student has shown active involvement at all phases of the experiential learning activity. The student have performed all the hands-on practices required for the conduct of the activity.	The student was involved in the all phases of the activity performed with necessary hands-on practices.	The student was involved in the activity; however does not exhibit hands-on contribution to some the phases.
Quality of Work Accomplished	Maintained excellent quality in the work in each phase of the task undertaken, meets the deadline, accurate and neat on routine	Maintained a good quality in the work with minimum errors. Meets the deadline for most of the time.	Mediocre quality of the work accomplished. Struggled to meet the deadline and errors in each phase of the work.
Critical thinking and analysis of the device	Exhibits excellent critical-thinking and analytical skills. The device fabricated was critically analysed and reported with proper justification in the report submitted.	Exhibits good critical-thinking and analytical skills.	Exhibits average critical-thinking and analytical skills.
Team work (Proper coordination, work allotment etc.)	The work and report submitted exhibits excellent team work with proper coordination among the team members with every team member contribution to the allotted work.	The work and report submitted exhibits team work with proper coordination.	Exhibits a team work with a fair degree of coordination among team members.

IV. RESULTS AND DISCUSSION

A. Improvement in CO Attainment

The figure 3 illustrates comparison of CO attainment for Engineering Thermodynamics course of current academic year (CAY) with previous academic year (PAY).

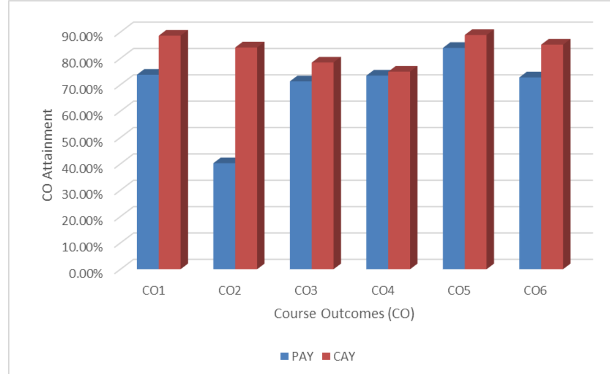


Fig. 3. CO Attainment for PAY and CAY

From figure it is evident that, experiential learning activity conducted in CAY have revamped attainment for CO1, CO2 and CO3 as compared to that of PAY. The significant improvement in the CO attainment can be seen for the CO1, CO2 and CO6 for the CAY in comparison to PAY. There is a slight increase in the CO3, CO4 and CO5 attainment for the CAY. From the course content it is perceptible that, the laws of thermodynamics are given emphasis in chapter 1 and 2 with prominence of first law of thermodynamics in chapter 1. The mentation behind conducting the proposed activity was to make students aware about PMM1 and in turn improve the grasp of laws of thermodynamics. The experiential learning activity conducted in this work focusses on the comprehension of the chapter 1 and chapter 2, hence it shows significant improvement in the CO attainment for the CO1 and CO2. In addition to this, the activity conducted in the initial weeks of the semester for engineering thermodynamics course increased interest and involvement of the student in the course which is also helped students to have better grasp of remaining part of the course.

B. Improvement in Average Marks

The average marks of students for all written tests (UT1, UT2 and ESE) are compared for PAY and CAY with the help of bar plot as represented in figure 4. The maximum marks for UT1 and UT2 evaluation is 25 while maximum marks for the ESE evaluation is 50.

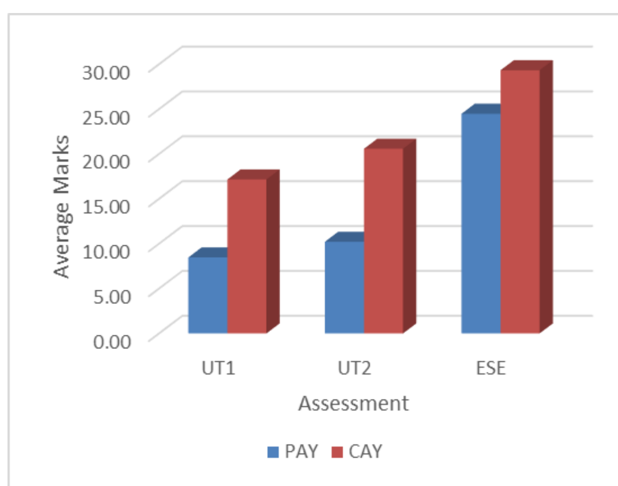


Fig. 4. Average Marks Comparison for PAY and CAY

It is evident that, average marks of students in all forms of written test have revamped in CAY as compared to PAY due to experiential learning activity conducted. The UT1 and UT2 question paper is based on chapter 1 to 4. The laws of thermodynamics is the prominent part of chapter 1 and 2 while availability and properties of gases are prominent part of chapter 3 and 4. Improved grasp of law of thermodynamics is reflected in the average marks of student for UT1.

C. Student Survey

To analyze the effect of experiential learning approach applied to validate PMM1 concept, the student feedback was also recorded. A student survey employing a questionnaire comprising of 7 questions was shared with students to record the responses. Table VII summarizes the student responses for the activity conducted.

TABLE VII
SUMMARY OF STUDENT RESPONSES

Sr. No.	Questionnaire	No. of Students Responded	
		Yes	No
1	Did you had proper understanding of PMM1 concept prior to experiential learning activity conducted?	21	53
2	Have you seen and believed the video of PMM1 claiming power generation without any external work on social media platform like YouTube?	41	33
3	Did your replica of PMM1 produced energy/work without aid of external work?	00	74
4	Do you agree with the claim to produce energy without external work made on social media platforms?	00	74
5	Did you enjoyed the experiential learning activity conducted?	68	06
6	Are you now well aware about the fact that no device can produce energy/work without any external energy?	74	00
7	Do you feel that you can retain the knowledge gained through this activity beyond the semester time-frame?	71	03

Around 71% students declared no understanding of PMM1 concept of thermodynamics prior to the conduct of this activity. The claim of power/work generation without providing any external work to a device made on online video sharing platforms like YouTube was believed to be true by more than 55% students. All students (100%) declared that the replica of the PMM1 claim fabricated by the students did not produced energy/work as claimed in the video and hence do not agree with the claim. As a consequence, all students have cleared that no device can produce energy/work without any external energy/work. Around 96% students are confident that they can retain the knowledge gained through the activity beyond the semester time-frame.

D. Effect of Quality of Input Students

The academic performance of students also depends on the cognitive level of the students in CAY and PAY. Students are admitted for first year of engineering on the basis of common entrance test (CET) marks. The average marks of students admitted for first year mechanical engineering course for PAY and CAY is 86.6 and 85.5 respectively. It is clear that the average marks of students for CAY are insignificantly less than that of PAY. It is perceptible to say that the improvement in the academic performance of students for engineering thermodynamics course in CAY is due to the activity conducted and is not impacted by the difference in the cognitive level of students.

V. CONCLUSION

It is concluded that, adopting experiential learning approach for validation of PMM1 helped students to have proper comprehension of basic concepts of thermodynamics. It also breaks fixed framework of learning and offers flexible framework of learning to students triggering creativity of students. It is also proved quantitatively that, academic performance of students in written test have been enhanced significantly. It is concluded that,

- The average CO attainment for the CAY boosted to 83.38% from 69.26% for the PAY.
- The squatted attainment for the CO2 for PAY uplifted to 84.15% from 40.24% due to conduction of experiential learning activity.
- The average marks for the UT1 and UT2 assessment increased by more than 100% in the CAY.
- The average marks for the ESE assessment revamped by 19.8% in the CAY in comparison to PAY.

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