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Analysis on the appropriate Pedagogy approaches applicable for 'Engineering Thermodynamics' Course*

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Teaching – Learning processes are vital in making the students understand better in diverse classroom environments. Few innovative approaches used may ensure that the class work is more interesting and make the students deliver better in order to gain the desired output, at the end of the course. Different aspects of T-L processes are possible to implement in all the courses, leading to any engineering program. With the invention of new technologies, these have got a new dimension, which are not so conventional as earlier. In this work, 'Engineering Thermodynamics' course, which is taught in an undergraduate energy engineering program is considered. Course contains five modules, covering fundamentals of thermodynamics, laws of thermodynamics, entropy, power cycles, fuels and combustion aspects. Different pedagogy approaches suitable according to the modules and the entire syllabus are exemplified and elaborated. Temperature and pressure measurement concepts can be taught effectively by the teacher by bringing the gauging equipment to the class. Laws can be taught with the help of a software, showing the uniformity of temperature or work done as per the heat input. Entropy can be taught with the practical examples shown in presentation/videos or through demonstration. Teacher can demonstrate an experiment in the lab to identify the performance of the engine, in order to make the students understand the concepts of power cycles. With the help of group tasks (or) case studies on live problems, the environmental aspects can be clearly understood by the students. In the end, grades obtained by the students and course-wise outcome attainment are also plotted for the last four years. Analysis finds the use of innovative pedagogy approaches, while sticking to the conventional teaching methodology, in order to ensure that students achieve the required abilities. Thus the present work uses appropriate pedagogy approaches applicable for a basic engineering course and is very much useful for implementation by the teachers of energy engineering and allied programs.

Keywords: Teaching – Learning process; Pedagogy approaches; Innovative teaching methods; Experiential learning; Collaborative learning

1. Introduction

Scenario of diminishing admissions in engineering institutes across the globe is seen as a major threat to the significance of technical education. Because of this, survival of the institutes and programs has been difficult. This is true for any engineering institute, irrespective of the types of programs offered. Accordingly, they are trying to improve the quality of Teaching-Learning (T-L) process, while opting for Outcome Based Education (OBE) and aiming for appropriate accreditation/certification. Entering the ranking framework at national or international level is also becoming unavoidable. In such a scenario, institutes or programs (either Under Graduate or Graduate), need to rely more on faculty and students. How best the faculty are teaching and how best the students are learning have been the main concern. This is possible only if appropriate teaching methods are applied in the classroom. Traditional teaching methods perceive that the teacher as the sender or source of information, whereas the student is the receiver of the same. More often, the chalk piece-black board kind of teaching is treated as the best one, but, it is mostly seen as one-way flow of information. Such practices do survive, if there is sufficient interaction with the students is followed at appropriate time intervals. Growing concerns for survival have made the management or authorities to instruct the teachers to adapt new and state-of-the-art teaching-learning methods as well. Such innovative pedagogy approaches can be like collaborative learning, group tasks, use of animations/power point presentations/videos, use of computational simulation, use of ICT (Information and Communications Technology) tools etc. These have been possible with the advancement of different new technologies and hence T-L processes have got a new dimension. This lead to improved teaching methods and changed learning patterns and the ways of assessment. Eventually, all the faculty associated with the conventional T-L processes are expected to adapt certain innovative teaching methods in delivering the course work, in order to make them updated in view of changing students' learning attitudes.

Earlier, Kastenberg et al. [1] identified an approach to undergraduate engineering education applicable for the present century. They recognized the characteristics of new technologies, implications of engineering education and pedagogy approaches. Later, Lawlor and Hornyak [2] acknowledged that framing of smooth learning outcomes would enhance students' performance.

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They supported the use of appropriate spreadsheet in preparing those outcomes, which would be more smart and apt. Borrego et al. [3] studied the effect of engineering teachers' T-L related philosophies on pedagogy in case of science courses. They conducted surveys in a specific region and acknowledged a number of common beliefs among teachers to improve students' learning and recommended few instructional strategies in their courses. Susan and Lisa [4] discussed the understanding aspect in case of engineering practice. Also, they suggested a new taxonomy in this area and applied to two engineering courses. Mirkouei et al. [5] presented a pedagogy framework that would support teachers in evolving education components. The framework also covers creation of instructional resources, live learning resources and a mechanism for cumulative evaluation in the area of manufacturing engineering. Kersten [6] discussed the method of engineering pedagogy to advance the quality of teaching in engineering education. It was more towards developing curricular structure, influenced by the demand, objectives and organization. Dzombak et al. [7] tried to examine the learning outcomes associated with the design programs and assessed the resemblances and variances among them. It was about finding the causes of differences and finally designing a multidisciplinary design based program. Recently, Aziz and Islam [8] explored the influence of combining several pedagogy methods to bring in good learning/understanding for online students, using problem based learning. They identified that the students' commitment and passion improved with integration of different approaches, while solving real-life problems. Earlier works tried to hint different pedagogy approaches or methods, in a general perspective. But, they have not been pertaining to a particular course or program. In this context, the present work deals with the T-L aspects of 'Engineering Thermodynamics' course, applying both conventional and advanced methods of pedagogy. This study will pave the way for teachers to stick to use appropriate innovative methods, without moving away from conventional teaching.

2. Methodology

In this work, a third semester Under Graduate energy engineering course like 'Engineering Thermodynamics' is considered for analysis. Initially, effort is made to understand the concepts covered and accordingly, appropriate learning outcomes are selected. The contents of the course are spread in five modules and is taken from a model curriculum, which is common to all the energy related engineering programs across India. Elsewhere also, similar topics are followed to cover such basic course. Based on the contents of each module, action verbs are chosen and Course Outcomes (COs) are prepared. Then, module-wise contents along with the selected pedagogy techniques are discussed. In the end, effect of implementation of such pedagogy methods is also discussed by considering the CO attainment for the last few years. Critical review of the methods applied here is also done and details of approach used and how knowledge is gained effectively are highlighted.

3. Pedagogy Approaches Applied for Various Modules

Thermodynamics is a course that deals with energy transfer and processes related to that. This course is generally offered in most of the core engineering branches except computer science, electronics and communication. The course contains five modules, corresponding to each module and the type of knowledge, expected abilities are to be outlined and accordingly, the teaching methodology has to be finalized. In order to achieve this, initially, the course outcomes need to be prepared, based on the anticipated capabilities. Subsequently, according to the module-wise outcome based scenario, appropriate pedagogy techniques are examined and suggested in the following sections.

3.1 Selection of Learning Outcomes

Selection of appropriate learning outcomes itself solves the problem by half. The first module deals with fundamentals of thermodynamics. The ability of understanding is achieved. 'Discuss' or 'Understand' seem to be the correct action verbs. Aptly, 'Discuss' is used. Second module covers the principles and laws of thermodynamics. Laws are applied to various thermal systems. The ability of applying the knowledge is accomplished. Hence 'Apply' seems to be the correct action verb. Third module covers the significance of entropy. 'Recognize' or 'Understand' seem to be the correct action verbs. Therefore, more relevantly 'Recognize' is used. Fourth module covers the investigation of several gas and vapour power sequences. The ability of analyzing is achieved. Fittingly, 'Analyze' seems to be the correct action verb. Fifth module covers the discussion on various fuels and combustion characteristics. The ability of understanding is achieved. Appropriately, 'Identify' seems to be the correct action verb. Topics to be covered along with the selected course outcomes for all the modules are shown in Table 1.

3.2 Pedagogy approaches for Module 1

Module 1 deals with the fundamentals of thermodynamics. It contains various definitions of thermo-

Table 1. Module-wise Course outcomes

Modules	On successful completion of the course, the students will be able to:
Module 1: Fundamentals of Thermodynamics	CO1: Discuss the fundamentals of thermodynamics.
Module 2: Laws of Thermodynamics	CO2: Apply the laws of thermodynamics.
Module 3: Entropy	CO3: Recognize the concept of entropy.
Module 4: Gas and Vapour power cycles	CO4: Analyze different gas and vapour power cycles.
Module 5: Fuels and Combustion	CO5: Identify various fuels and combustion characteristics.

dynamics, systems and types of systems, their properties, processes and characteristics. The theoretical aspects can be taught by the conventional method, using chalk piece-black board. For better understanding of the same, the teacher can bring the lab components to the class, like pressure gauge, thermometers, manometers etc. By showing the Bourdon's pressure gauge in the class, if the teacher explains how the pressure is measured, students will be able to remember the same for long and apply the same during assessment for obtaining better grades. Through the demonstration of either manometer or thermometer, the teacher is trying to induce the practicality component in the theory based course to improve the learning aspects. Same way, to exemplify various systems, the teacher can take the help of models or miniatures of different systems.

3.2.1 Bringing Lab Components to the Class

To obtain any science or engineering degree, a student has to cover nearly 45–50 courses. In particular, the engineering student goes through different types of equipment, systems and devices. This makes the student to memorize large amount of information. Remembering things discussed in a class can be easy, but, when it comes to a greater number of classes, it will be difficult and more frustrating. But, through practicing visualization technique, one can be able to remember large chunks of information quickly. Also, such techniques enable the student to remember some concepts for years together or life-long. Simply, the demonstration of pressure gauge to the students of undergraduate energy engineering program in a thermodynamics class will give outstanding results. Also, to make the students understand about various types of systems, reversible and irreversible processes, a greater number of practical examples are available.

3.2.2 Using x-y Plotter

To explain the P-V diagram of different thermodynamic processes, teacher can use any x-y plotter and draw the same using different values and the students will be able to understand better. For different types of processes, the diagram will change accordingly. Similarly, for the given set of different values of pressures and volumes, students can plot and identify the type of process easily. Fig. 1 shows the theoretical aspect of the P-V diagram for a thermodynamic system involved in various processes. There can be different values of pressures, volumes, polytropic indices (n) and ratios of specific heats (γ). Constant pressure and constant volume processes are represented by a straight line in the P-V diagram. Curves of isothermal, polytropic and adiabatic processes will fall in between these two straight lines. Fig. 1 also shows the teachers' interpretation of the same through a

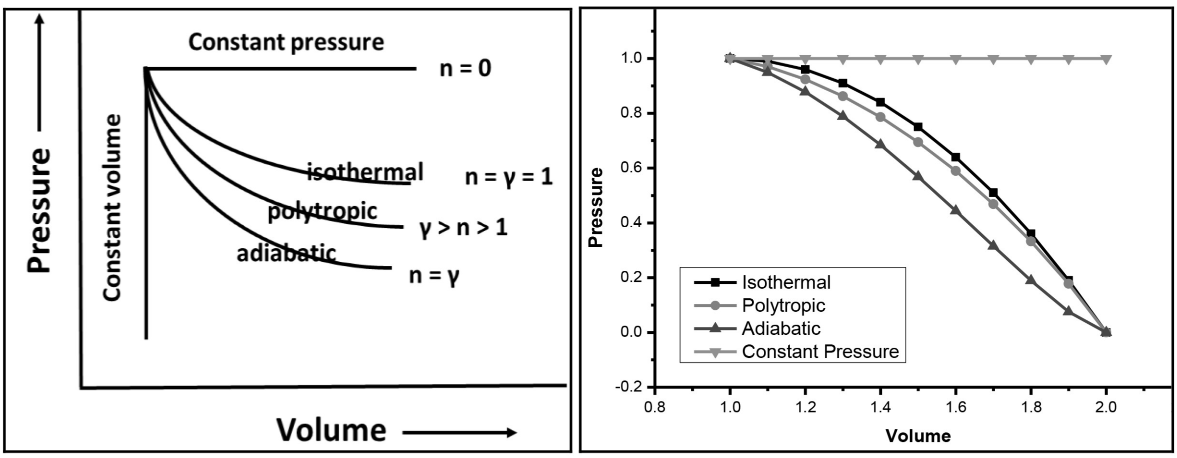

Fig. 1. Theoretical and practical aspects of the P-V diagram for a thermodynamic system.

numerical example in the class. Students can prepare the plot by using different values of P, V, n and γ as a part of an assignment.

3.3 Pedagogy Approaches for Module 2

Second module covers the laws of thermodynamics. This module also discusses their importance and necessity of defining the same, which are about attaining procedural knowledge. During the class room interaction, first and second laws of thermodynamics are discussed with examples.

3.3.1 Use of Computational Simulation

For explaining the same, the teacher can use simulation software available (or) prepare a computational tool, as shown in Fig. 2. It demonstrates the use of a simulator to explain zeroth law of thermodynamics. Initially, the three bodies A, B and C are not in contact with each other. After some time, bodies A and B, bodies B and C and bodies C and A will be in equilibrium with each other. After a certain amount of time, all the three bodies, A, B and C will be mutually in equilibrium with each other. It means that the three bodies will come to an equilibrium state in certain amount of time. Demonstration through the simulation will ensure that the student remembers it for long. This way, by observing, the student will be able to learn the concept and practices doing the same, what he has observed during the learning process. Such simple simulation software are available in open-source and are easily available to the students (or) the teacher. Anyway, observation is always the first step for learning something. These simulation tools give the learner or the student, a chance to run-through real-time situations and moreover, they replicate what actually would have happened. Through such simulations, one can precisely demonstrate real actions and certainly provide a quicker, economical and an effective way of improving the leaner's expertise and capabilities.

3.4 Pedagogy Approaches for Module 3

Third module covers the concept of entropy, entropy generation and entropy change for various processes and systems. Every irreversible process is associated with the increase in the entropy of the universe. Simply, irreversibility or loss in case of a system is referred as entropy. The definition and importance aspect of losses and role of entropy in various thermodynamics systems is discussed. This is related to the achievement of some conceptual knowledge.

3.4.1 Simple Practical Exposure

To make the students understand the concept of entropy, supporting instances are required to show that energy cannot be fully convertible to useful work always and there will be losses. Teacher can give them the task of 'weight and pulley' and ask them to repeat the same, which they would not be able to. Visualization through presentation/videos, showing that the entropy of universe is increasing (or) there will be losses associated with any operating system is also a good idea. The same can be easily explained through the practical demonstration of 'running a bicycle' (or) 'operating a fan/

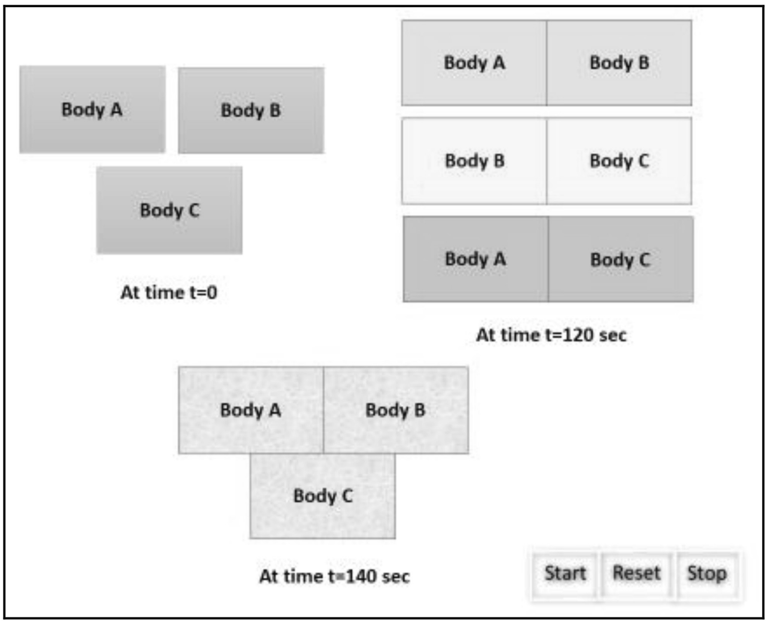

Fig. 2. Use of computational simulation to prove zeroth law of thermodynamics.

compressor'. After running a bicycle/fan/compressor, it shows acquiring losses as the components gets heated up (or) generate sound/vibration, after certain number of cycles. Students will be able to clearly understand that such heat exchange (or) energy exchange will lead to entropy change. Demonstration through such practical experience is useful and easily manageable, as shown in Fig. 3. Also, by showing the examples of an isolated system like flask or an ice cream container, teacher can discuss the concepts of entropy.

3.4.2 Use of x-y Plotters and Calculators

A software or x-y plotter can be used by the teacher to discuss the entropy variation in different processes with change in temperature and pressure conditions with specific heats at constant temperature and pressure given. Same way, built-in calculators available online/off-line can be used by the teacher to demonstrate the easy calculation of different properties of a thermodynamic system, throughout the 'Engineering Thermodynamics' course.

3.5 Pedagogy Approaches for Module 4

Fourth module covers the analysis of various gas and vapour power cycles. This is gaining procedural knowledge and comparing the same for different applications. Drawing the schematic diagram of the cycle or equipment in the class and explaining the same will be helpful. One need not draw the complex diagram of the setup on board. It can be a schematic or representative one. Instead, with a simple experiment on either diesel (or) petrol engine, students will be able to understand the working of the cycle for long and gain more marks as these are asked as essay type questions during assessment.

3.5.1 Demonstration of the Experiment

A teacher can demonstrate the experiment and show how efficiency varies with load and explain how different engines work. Without running the engine also, it will do the needful, if the teacher explains the parts of the engine and how it works. Complete demonstration of the engine or gas power cycle by the teacher in thermal engineering lab can be effective. Even numerical problems based on that also, they will be able to solve in the examinations. Using such scenario, the students' understanding and scoring grades are also improved. Practical work really encourages self-learning. It familiarizes the students about how the engine works and the processes, parameters and the expressions involved. Also, practice leads to perfection. Rather than conveying the same knowledge through black board/white board, it is better to ensure that the students learn through experimentation in the lab with minimum input in the class. This not only makes the students learn faster, but also, enable them to gain better grades.

3.6 Pedagogy approaches for Module 5

The fifth module covers the aspect of fuels and combustion. It is about fundamental knowledge related to different fuels and their characteristics. This is related to gaining conceptual knowledge. In this subsection, the teacher can give group tasks or assignments on live problems. Also, preparation of models or charts by the students related to the equipment used for flue or exhaust gas analysis will be innovative.

3.6.1 Case studies by Students in Groups

For proximate or ultimate analysis of coals, collaborative learning method can be applied. Based on the knowledge gained in the class, students analyze

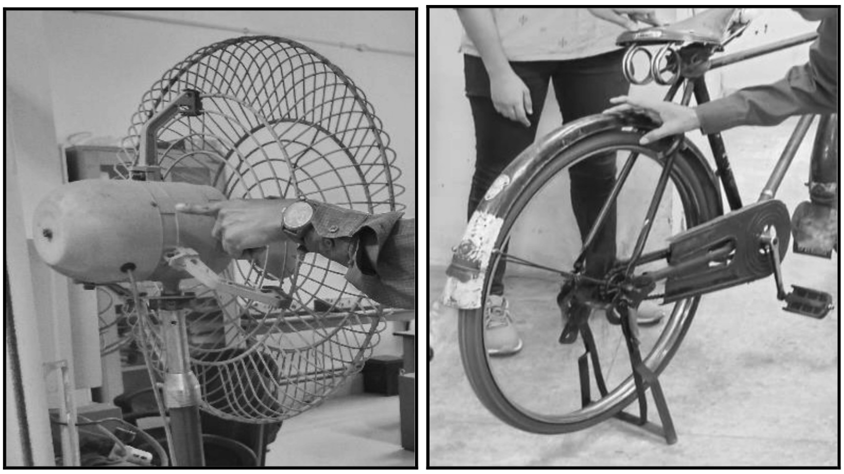

Fig. 3. Demonstration of the running of a fan and cycle.

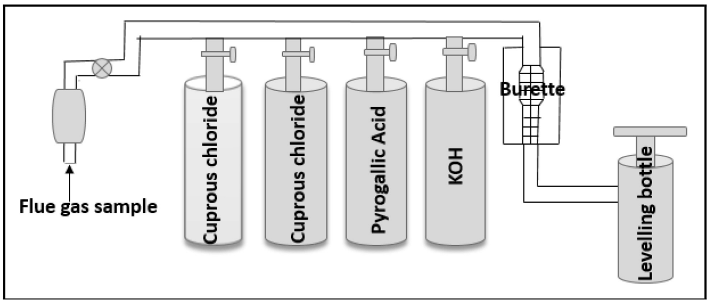

Fig. 4. Preparation of the model for exhaust gas analyzer.

different types of coals and identify the suitable coal (or) simply, the best coal available for Indian power plants. Using various numeric processors available, students can select suitable coal, whether it is Indian coal (or) African coal (or) Australian coal. Normally, in coal, low ash and moisture contents are expected. This task can be given to 12 groups of a 60 student capacity class. The effect of conducting the case study in groups will be more effective to learn the things efficiently. Definitely, sharing of knowledge will be taken care along with the development of high-level thinking and improved technical communication.

3.6.2 Preparation of Models/charts

After teaching the theory in the class, teacher would give a task to select groups or bright students to prepare the proto-type model of an exhaust gas analyzer using the equipment available in thermal engineering lab. A model for the exhaust gas analyzer prepared by the students is as shown in Fig. 4. If that is not feasible, charts can be prepared by the students for the teacher to use the same in future. While doing so, understanding the concept in case of the students involved will be good, as they learn while practicing.

Table 2. Specimen regulations for deciding the levels attained

Attainment levels	Indices
Level 1	60% of the students scoring more than the reference mark.
Level 2	70% of the students scoring more than the reference mark.
Level 3	80% of the students scoring more than the reference mark.

4. Effect of Implementation of Such Pedagogy Methods

In the earlier sections, different pedagogy approaches relevant for 'Engineering Thermodynamics' course are discussed. Such a scenario has a valid point, only if the grades of the students are also considered and improvement is obtained, when compared to earlier instances. Marks of the students for the last four years are collected and plotted as shown in Fig. 5(a). For the earlier batches of 2017–18 and 2018–19, the average mark was slightly low. For the last two years, it has been good. This clearly shows that the implementation of appropriate pedagogy approaches is giving favourable results. Similarly, for any course, if we follow such methods meticulously, improvement of students' understanding and thus the grades of the students may increase.

Further, the overall attainment of the course for

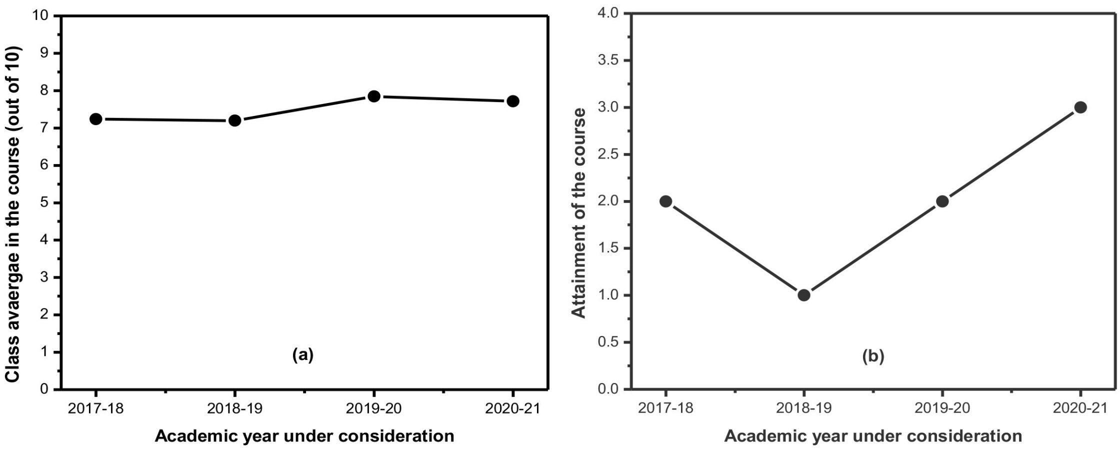

Fig. 5. Average grades obtained in the course for the last four years and CO attainment.

the same period is calculated and plot is made for comparison as shown in Fig. 5(b). CO attainment is based on the marks scored by the students in the examinations and the levels obtained by the students based on those marks. Level will be higher if more students score more than the reference mark used for the CO attainment calculation as shown in Table 2. Then, course-wise CO attainment is treated as good. Initially, the marks of all the students are collected. Reference mark or average mark is identified. In the present case, grades or marks are given by the university, based on both internal and external examinations. For example, based on the marks scored by the students for the year 2020–21, it is observed that 80% of the students of the scored more than the reference mark. Therefore, the CO attainment = 100%*3 = 3. Earlier, 70%, 60% and 70% of the students crossed the reference mark for the years 2019–20, 2018–19 and 2017–18 respectively. Accordingly, the course-wise CO attainment has been 2, 1 and 2 for the previous years.

Strikingly, the CO attainment has been in the improving pattern over the years. In the recent academic year, the attainment has been the highest. This shows that the pedagogy approaches applied have been at their level best. In the scenario of changing trends and growing competition, by adapting appropriate pedagogy approaches, one can achieve course-wise outcomes efficiently. If the same is successfully applied to all the courses of the program, it is easy to accomplish program outcomes as well. Thereby, one can ensure that their programs are better accredited and recognized, which will be helpful for the long running of the institute.

5. Critical Review of the Pedagogy Approaches Adapted

Thus, in the course under consideration, the teacher uses good number of pedagogy approaches. Definitely, as anticipated (or) required, effort put by the teacher is more and the effort required by the students is less. Main aim has been to make the students understand the concepts of thermodynamics better. Different approaches adapted in this work are tabulated as shown in Table 3. Also, additional uses of adapting such approaches are presented.

1. Demonstration helps the students' learning process by visualizing particular concepts or working procedures. As the students see what happens, they visualize those concepts correctly and remember the concepts for long and this ensures scoring of marks in different examinations. Even after the completion of the course/program, they would be able to recollect/remember.
2. Use of computational simulation tool or x-y plots to show some of the principles or processes will allow the teacher and students to explore more real-time situations. Such simulations can trigger several skills in learners like predict and control variables, formulate new scenarios, apart from interpreting results in a nice way. Also, they increase the interest of the students to attend the classes more.
3. Simple practical exposures used will increase the concentration of the students, which is essential for learning and growth. Here, they try to absorb and understand the information, when they focus on a task or theme or object. If that is a real-time or day-to-day example like cycle/fan, they will really appreciate it more.
4. Demonstration of the experiment ensures that the students understand the concepts better. It makes the students to be more creative and it is not possible to have improved attitude towards learning.
5. Case studies by student groups will create more opportunities for critical thinking and can encourage student learning and accomplishment. It shows increased individual achievement, enhances communication and other professional development skills. Preparation of models/charts will make the students to be more creative and learn, while making new things. It allows them to be more perfect, while overcoming the mistakes done.

Table 3. Pedagogy approaches adapted

Module Number	Teaching methodology adapted	Related pedagogy approaches	Additional uses
1	a. Bringing lab components to the class. b. Use of x-y plots.	Concentrated learning, Instructional pedagogy.	Visualization helps the students remember for long.
2	a. Use of computational simulation tool.	Instructional pedagogy.	Explore more real-time situations and develop interest in the class work.
3	a. Simple practical exposure. b. Use of x-y plotters and calculators.	Concentrated learning, Instructional pedagogy.	Increase the concentration and growth of the students.
4	a. Demonstration of the experiment.	Experiential learning.	Increases the creativity of the students and interest in learning.
5	a. Case studies by students in groups b. Preparation of models/charts.	Collaborative learning, Experiential learning.	Increased individual achievement and learn while making new things.

This work suggests easily applicable pedagogy scenarios, making the T-L processes more interesting and at the same time, students' objectives are also fulfilled. Also, it gives hints about the appropriate pedagogies at appropriate places/topics, without disturbing the conventional teaching (black board/white board) of such fundamental courses. Suggested pedagogy approaches won't disturb the class work much. Only in the 4th module, one lab visit is proposed. It is not uncommon that teachers have different techniques to make the students understand a particular topic (or) scenario. Teachers find it better to teach this course using chalk-piece black-board, than using power point presentation. On the other hand, researchers do talk about innovative pedagogy approaches all the time. Using them when absolutely necessary, and up to certain extent is what is actually needed. In such a scenario, this work would be a tailor-made one and easily implementable for all courses.

6. Conclusions

In this work, different pedagogy approaches suitable for an undergraduate energy engineering course like 'Engineering Thermodynamics' are studied. Module-wise outcomes are framed and accordingly, concept based pedagogy techniques are discussed. Practices such as bringing lab components to the class, use of x-y plots, computational simulation, demonstration of the experiment, case studies by students in groups and preparation of models/charts are applied by the teacher, while covering the five modules of the course. Work involved by the teacher outside of the class is very much limited and involves only one lab visit and demonstration of few practical components. Approaches such as concentrated learning, instructional pedagogy, experiential learning and collaborative learning are found to be suitable. Advantages of adapting such practices are also elaborated. Such innovative and appropriate pedagogy methods discussed here have not only improved the average grade point gained by the students, but also the course-wise CO attainment. These can be easily implemented for similar engineering courses. The present work will also help the teachers in enhancing their knowledge in implementing appropriate pedagogy aspects according to the syllabus, while teaching any such energy related engineering courses.

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