Implementation of Problem-Based Learning (PBL) in Chemical Thermodynamics Course at the Yanbu Industrial College, Saudi Arabia

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Abstract

This work is focused on the strategies used to incorporate PBL in chemical thermodynamics course taught at the chemical engineering department at the Yanbu Industrial College, Saudi Arabia. The course was redesigned to map course learning outcomes with the learning objectives. From a dominant traditional teacher-centered course, a framework was developed to introduce student-centered learning. In the student-centred learning section, PBL was incorporated in the 10th week of the course where intention was to cover most course learning outcomes. As a starter, the PBL formed only 13% of the total teaching and learning hours for the course. The multiple-solution problem encompassed the use of energy transformation to economically and efficiently transport natural gas from far areas to populated cities. It was found that PBL could be used as an effective education strategy for a typical chemical engineering course albeit teacher-centred approach could not be eliminated completely.

Keywords: chemical engineering, problem based learning, thermodynamics

1 Introduction

Yanbu Industrial College (YIC) was established in 1989 to meet the growing demand of technical hands for chemical and allied industries. Since then the revolutionary changes in engineering and technology have forced industries to seek engineers and technicians that are critical thinkers, problem solvers and highly motivated self-directed learners. Naturally, YIC is striving hard to produce quality graduates that could satisfy its stake holders. The ongoing effort, apart from hiring highly qualified faculty and renovating its infrastructure, is to update its curricula and to incorporate advanced teaching methodologies. A recent step in this direction is the implementation of Problem-Based Learning or PBL due to its increasing popularity in academia worldwide.

Research in education indicates that by having students learn through the experience of solving problems they can learn both content and thinking strategies [1]. PBL is a student-centered instructional strategy in which students learn through facilitated problem solving. In PBL, student learning centers on a complex real world problem that does not have a single correct answer. Students work in small to medium groups to pinpoint what they need to learn in order to solve a problem. They engage in self-directed learning and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed. In other words, PBL gives four dimensions to the process of learning such as constructive, self-directed, collaborative and contextual. The teacher acts to facilitate the learning process rather than to simply provide knowledge. Thus the role of teacher is to help learner to develop metacognitive skills associated with problem solving process encouraging them to think both critically and creatively.

PBL has been shown by many researchers as a very effective tool in enhancing student learning [2-4]. The results of a number of empirical studies on PBL in post secondary education by Dochy et al [5] indicate that students taught under PBL environment are shown to possess greater positive skills compared to traditional teacher-centered education. Because it promotes deep learning and problem solving skills, PBL has been highly recommended in engineering disciplines as well [6-7]. However, PBL is not free from criticism [5,8]. The disadvantages cited are: i) students cognitive knowledge may have gaps and they may not develop expert reasoning patterns ii) costly and iii) negative effect on knowledge. The institutes have therefore cautiously adopted this learning strategy. Usually a blended approach that is combining PBL with traditional lectures is recommended. More details about PBL can be found elsewhere [9-12].

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Realizing the overall benefits of PBL, the administration at YIC has recently started a program in cooperation with German Malaysian Institute (GMI) of Malaysia to implement this education strategy in all its engineering disciplines. The awareness among faculty members and students is being made about the key techniques of PBL through seminars, workshops and online tutorials. At present the PBL is in the nascent stage in the college and therefore a micro-level approach [1] has been taken into consideration where instead of revamping the major course curricula certain topics in a course are being taught under PBL framework within a certain amount of time.

In this work micro-level implementation of PBL in chemical thermodynamics course taught at the department of chemical engineering technology is presented. In what follows a stepwise approach is delineated to fit PBL in a traditional teacher-centred course. The techniques of crafting a real world problem are also explained. Finally, the outcome of this effort is discussed.

2 PBL in Thermodynamics Course

The chemical engineering technology department at the YIC offers a three-year associate and a five year undergraduate degrees accredited by ABET. The thermodynamics course is offered at both levels as a compulsory 3.0 credit-hour course. This study focuses on the thermodynamics course taught at the associate level. The teaching methodology so far used is a traditional teacher-centred, that is, teacher delivers the lecture in the class, distributes handouts and give assignments and quizzes. There is also a mid-term exam and a final exam. The theoretical concepts are reinforced with laboratory experiments where same teaching style is adopted. The course learning outcomes (CLOs) are outlines below which are covered in five modules in 14 weeks time.

Student should be able to:

1. Explain the basic principles of engineering thermodynamics and develop the ability to reason from principles.
2. Recognize the importance of conversion of energy obtained from fuels into useful work required to drive modern industrial machinery.
3. Apply the basic thermodynamic principles to engineering equipment utilized in chemical industries.
4. Solve various thermodynamic problems using graphical and tubular thermodynamic properties of fluids.

Under these CLOs the course contents taught are summarised in Table1. In order to infuse PBL at an appropriate level and time length the course contents were first rearranged with CLOs and their duration was divided between Student Centred Learning (SCL) and Teacher Centred Learning (TCL). It was decided to introduce a PBL activity at the 10^{th} week of the semester where about 70% of the course was supposed to be covered and students already had a good amount of course understanding. Moreover, the course content taught at week 10 covers all CLOs as shown in Table 2. About 4 teaching hours were allocated for PBL which formed 13% of total teaching hours. After redesigning the course syllabus the next step was to craft the problem which is discussed next.

2.1 Crafting Problem Statement

The success of PBL depends heavily on how the problem is crafted and presented in a PBL environment. A good problem should motivate students for deeper understanding. Moreover, it should be complex, real word, multi-dimensional, open ended and must revolves around the CLOs [13]. In writing a complex problem other things to be considered are the level of difficulty and challenge that students can handle, should invigorate collaborative inquiry, its structure, and availability of information and resources.

Moreover, a good problem statement consists of a scenario which sets the context of the problem. This scenario in turn should consists of triggers or key words that would guide students how to start and where to go. In addition, it should contain hooks which engage students in the context of the problem. Good examples of hooks are article, video or picture etc. Following these guidelines a complex problem about gas transportation was constructed as given below in Fig. 1.

Table 1: Course contents to cover course learning outcomes

Course Contents	Learning Objectives	Course Learning Outcome			
		CLO 1	CLO 2	CLO 3	CLO 4
1. Understand Basic Concepts of Thermodynamics	Define fundamental terms. Identify Energy forms	X			
	Equipment's Thermodynamic Analysis		X		
	Laws of Thermodynamics	X			
2. Thermodynamics Systems, Energy Conservation, Basic Equations for Thermodynamics Laws	Principles of thermodynamics Systems	X			
	Define close open systems	X			
	Apply conservation of energy principles			X	
3. Gases, Single Phase , Boyels Law, Heat Capacities Entropy	Write Equations	X		X	
	Define Fundamental Terms	X			
4. Steam and Two Phase Systems, Boilers, Steam Traps, Property Tables, PVT diagrams, Compressors	List main features of boiler			X	
	Explain main features of Steam Power Plant				X
	Analyze essential features of PVT	X			X
	Compressors	X	X		
	Calculations for Compressors			X	X
5. Vapor Cycles & Applications Steam Power Plant Carnot Cycle Rankine Cycle Reversed Carnot Cycle Refrigeration Cycle	Describe Vapor Cycles	X		X	X
	Describe Steam Power Plant	X		X	X
	Describe Carnot Cycle	X		X	X
	Describe Refrigeration Cycle	X		X	X

Table 2: PBL Curriculum Design

Module	Course Learning Outcomes	Student Centered (PBL) (Content Covered)	Duration (hrs)	Teacher Centered (Content Covered)	Duration (hrs)	Total Duration (hrs)
1	CLO1 , CLO 2	0	0	06	06	06
2	CLO1 , CLO3	0	0	06	06	06
3	CLO1, CLO3	0	0	06	06	06
4	CLO1,CLO2, CLO3, CLO4	01	4	01	02	06
5	CLO1,CLO3, CLO4	0	0	10	06	06
Total Duration (hrs)			04		26	30
% Duration			13%		87%	100%

Problem Statement:

Transportation and distribution of fuels safely and economically requires important engineering skills. For example, the Natural gas is a very important industrial and domestic fuel and its transportation from wells to the final customer incurs major costs.

You are recently hired by a gas distribution company which is planning to supply natural gas to the city of Dammam as well as to transport it to Hail some 1197 km away from Dammam. Your boss has assigned you to come up with a viable solution of this task. The gas is available at 1 bar and it is estimated that a pressure of 500 bar is needed to deliver the gas at the Hail. What would you do? You might want to consider the following

1. Methods to transport the gas and their selection.
2. Equipment needed and their sizing/power and operation
3. Safety Considerations
4. Environmental Issues

Present your findings to the class in ½ hr presentation and submit a complete report elaborating your strategies to solve this problem and summarize your learning issues.

Resources

1. Thermodynamics – An Engineering Approach by Cengel and boles.
2. www. naturalgas.org/naturalgas/distribution/

Fig. 1 Problem Statement

A careful analysis shows that the problem covers all four learning outcomes given above. This is summarized in Table 3. In addition, it shows a real world engineering task of preliminary design of a gas transportation facility. The problem is ill-structured as it provides minimum data. Triggers are underlined and a scenario is developed to invoke the interest of student whereas hooks are incorporated under resources. Topics such as environmental concerns and safety are included to make students think beyond the course contents. Students were given one week to find multiple solutions to this problem and they were required to present their work in a 15 minutes presentation to the class. In order to forecast students responses a FILA Chart was used (Table 4). An empty FILA chart was also handed over to students so they could figure out what they already know about the problem, jot down their ideas and learning issues and develop their actions plan.

Table 3. CLOs covered in the problem

Learning Outcomes	Problem's Solution
CLO1	Methods of Transport and Equipment Description
CLO2	Equipment Operation
CLO3	Equipment Sizing Calculations
CLO4	Equipment Sizing Calculations

Table 4.Facilitator's Fila

FACTS	IDEAS	LEARNING ISSUES	ACTION PLAN
Students know about compressors and how to calculate their efficiency. Energy conservation and transformation. Natural Gas as fuel.	Search internet and read books to find types of transformation methods. Formulate first law and simplify it for the compressors. Read property tables. Compare effectiveness of methods.	How to select the best option. Safety of the process. Equipment Sizing Calculations. Use of Excel for solving equations	Class Notes Handbooks Textbook Internet Search. Ask Teacher Ask Seniors Ask industry experts.

2.2 Problem Implementation

To implement the problem the students were divided into six groups with each group consisting 5 students for a class of 30 students. The number of groups and size were considered manageable for a single teacher without assistance. The teacher acted as a facilitator to ensure self directed learning for students. Moreover, with this number of groups facilitator had no difficulty to walk around the class, to intervene at key point to promote discussions and resolve conflicts or dysfunctions, and to gather class for a brief period to discuss overall progress. The groups were formed by mixing students of high and low GPA so that an atmosphere of competition among groups be prevailed. Roughly four class hours were allocated for this PBL activity. At the end of the activity the groups presented their results in a 15 minutes presentation.

2.3 Results and Discussions

This was the first time students and the teacher carried out PBL activity in the thermodynamics class. On the part of teacher it was quite pleasing experience to deliver the course contents in such a way. Teacher realized more interactions with the students and be able to clearly understand their difficulties in solving the problem. Teacher also learned to handle group dynamics. However, teacher found it quite laborious to guide students because of their inability to grasp the problem completely. At times, teacher had to give short traditional lecture to guide students.

On the part of students they were puzzled and looked frustrated initially because they were not accustomed to work on a complex problem as groups in class but with the passage of time they looked settled and motivated. At the end of the activity when students were asked to comment on PBL methodology the majority agreed that it promoted better understanding of the problem, improved communication skills during discussions with team members and the facilitator and exposed new ideas in a short time period. During class presentations following strengths and weaknesses of students were revealed:

1. All groups reached the conclusion that transporting gas by using large size compressor was the preferred option over distributing gas in cylinders. They justified their choice owing to large populations in both cities would incur huge costs for latter choice.

2. Only one group performed the sizing calculations accurately by taking non-ideal gas behaviour into account at high pressures. Some groups also made mistakes in unit conversions. The groups differed in choosing the type of compressor. Two groups suggested reciprocating compressor while the rest came up with the idea of using centrifugal compressor. However they did not justify their selection.

3. Regarding safety and environmental issues most of the groups touched these topics generally with no reference to the main problem. It was not unexpected though because their non familiarity with these subjects. These topics were added to instil in students to discover new engineering horizons at their own.

Based on the written report, presentation and in-class group discussions the teacher's assessment of how successful the PBL activity was in achieving the CLOs is shown in Figure 2. Most of the group performed satisfactorily except Group-4 and Group-3. One possibility for these groups performing low might be random selection of students.

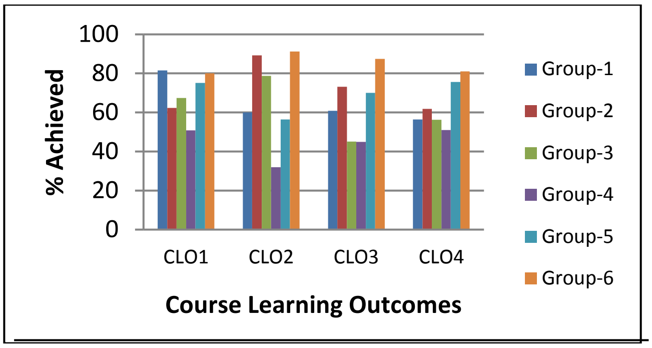

Fig. 2 % Achievement of CLOs

Analysis of percentage of skills gained in PBL was also carried out. This is shown in Fig. 3.

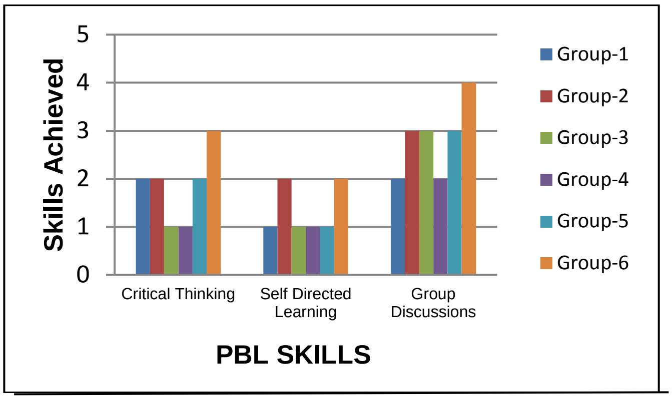

Fig. 3 Assessment of PBL Skills

In the analysis shown in Fig. 3 '1' was given the rating of very poor, '2' as poor, '3' as good, '4' as very good and '5' as excellent. As it can be seen the ratings in case of critical thinking and self directed learning were mostly found poor. The apparent inability of students in these skills clearly stresses to call for PBL implementation into the curriculum.

3 Conclusions and recommendations

Several conclusions were drawn from this study as follows:

- Traditional teacher-centred methodology cannot be completely eliminated at the associate-level degrees unless students are taught PBL at secondary schools or have sufficient experience of PBL in pre-requisite courses.

- Problem crafting should be done carefully. In this activity the teacher should also consult his colleagues and review his problem with them. In fact a committee should be formed to analyze and approve problems before those are presented to students.

- Formation of groups to promote collaborative learning should be done at the start of the course and before the implementation of PBL. This would help resolve issues among group members and improve their understanding towards each other before they embark upon PBL. This would ensure productive learning where each member of the group would be involved.

- The teacher's attitude to conduct PBL is very important to keep students motivated and focused on their problem. Teachers should be trained to play the role of an effective facilitator.

- While the problem is crafted based on CLOs the assessment should also be done to see whether those outcomes are achieved or not.

To summarize, a carefully crafted problem facilitated by a trained teacher in an effective PBL environment can invigorate important skills among students to meet industrial requirement.

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Biography

Ibrahim Mustafa is an assistant professor in the department of chemical engineering technology at the Yanbu Industrial College Saudi Arabia. He earned his B.E in chemical engineering from the NED University of Engineering and Technology, Karachi, Pakistan (1989), his M.S in chemical engineering and petroleum refining from the Colorado School of Mines, Golden, Colorado, USA and D.Sc. in chemical engineering from the Washington University in St. Louis, Missouri, USA. He is a member of the PBL committee at the YIC.

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