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COURSE OUTCOMES ACHIEVEMENT IN FUNDAMENTALS OF THERMODYNAMICS COURSE THROUGH DIRECT AND INDIRECT MEASUREMENT

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Abstract

In an outcome based education (OBE) system, a lecturer teaching any course should outline course outcomes in the course syllabus. Course outcomes are attributes or skills to be achieved by students when the course is completely delivered at the end of a semester. The Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM) has adopted the OBE approach since Session 2005/2006, in which states that a course syllabus should contain the course outcomes. In the Department of Chemical and Process Engineering, basic concepts of thermodynamics has been taught in a course, known as KKKR1134 Chemical Engineering Thermodynamics I, in Semester I for first year students. In order to improve the teaching and learning of this course, a questionnaire; an indirect measurement of course outcomes, was distributed to the first year students to obtain their feedbacks on the achievement of the course outcomes at the beginning and the end of the semester. The course outcomes based on the student perception was compared with the student achievement of course outcomes through examinations, quizzes, laboratory and integrated project. Based on the comparative analysis results using T-test, the student achievements of all the course outcomes through direct and direct measurements differed significantly. The students felt that they have grabbed the understandings and skills of the course outcomes. However, through their collative performance from the examinations, quizzes, laboratory and integrated project, their achievement of the course outcomes are lower compared to their perceptions. The findings can be the guidelines for the lecture who teaches the course to further improve the delivery so that all students can have a much better understandings on the thermodynamic concepts and achieve the course attributes confidently in examinations and project.

Keywords: Course outcomes, Concepts of thermodynamics, Indirect measurement, Students' perception.

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Nomenclatures

$\dot{E}_{in}$	The rate of energy in, kW
$\dot{E}_{out}$	The rate of energy out, kW
E_{in}	Energy in, kJ
E_{out}	Energy out, kJ
KE	Kinetic energy, kJ
m	Mass flow rate, kg/s
PE	Potential energy, kJ
Q	Heat, kJ
$\dot{Q}$	The rate of heat transfer into the system, kW
W	Work, kJ
$\dot{W}$	The rate of work transfer, kW
S_{in}	Entropy in, kJ/K
S_{out}	Entropy out, kJ/K
S_1	Entropy at point 1, kJ/K
S_2	Entropy at point 2, kJ/K
S_{gen}	Entropy generation, kJ/K
T_k	Temperature, K
U	Internal energy, kJ
Greek Symbols	
ΔE_{sys}	Energy change of system, kJ
$\Delta \dot{H}$	The rate of enthalpy change, kW
Δm	Change of mass flow rate, kg/s
ΔS	Entropy change, kJ/K
ΔS_{surr}	Entropy change of surrounding, kJ/K
ΔU	Internal energy change, kJ

1. Introduction

The Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM) has adopted the Outcome-Based Education (OBE) [1] for all the programmes offered in the faculty since Semester I Session 2005/2006 [2]. All the programmes have outlined the program educational objectives (PEO) and programme outcomes (PO) at the program level. PEOs are the attributes that graduates from a programme should achieve within 3-5 years after graduation. While, PO are the attributes that students should achieve just after completing a 3 or 4-year programme in the university. These PEOs and POs are correlated to each other, with POs contributing to PEOs.

At the course level, learning course outcomes (CO) that will later contribute to the enhancement and continual quality improvement of a programme are measured. According to [3], learning outcomes or course outcomes are statements of what a student is expected to know, understand and/or be able to demonstrate after completing a cycle of a learning process. Any lecturer who teaches a course under an OBE system should include the COs in the course syllabus and inform to his/her students in during an introductory lecture of the course content at the beginning of the semester. These COs are an essential part of a teaching and learning process that should be highlighted to students when a semester begins so that students should have a clear overview of what he or she should know, understand, able to do regarding the attended course. At the end of a semester, the lecturer is also recommended to stress again the COs so that the students can flash back and review of what has been covered in the course throughout the semester. The students can ask themselves whether they have grabbed all the attributes and take appropriate actions on any CO that they are lacking of. From the perspective of lectures, they can analyse the student performance on the achievements of the CO to further improve their delivery methods in coming semesters or sessions. The CO achievement can be assessed through direct and indirect measurements [4]. The direct measurements include through grades of quizzes, tutorials, projects and examinations. On the other hand, the CO achievement by students can be assessed indirectly through course evaluations (during the semester and end-of-semester). This measurement can be conducted through a survey from which the feedbacks will portray the achievements of the COs based on students' perception.

This action research aims to compare the achievement of course outcomes for the fundamentals of thermodynamic course through an indirect measurement of a questionnaire with direct measurement of course outcome achievement by students through mid-semester and final examinations, laboratory work, quizzes and integrated project.

2. Fundamentals of Thermodynamics

Thermodynamics is a course that explores the concepts of heat and how it can be converted to power, and covers all aspects of energy and energy transfer including power production, refrigeration and property relation of substances. This course has a history of being labelled as one of tough courses. Therefore, it is a challenge for any lecturer who teaches thermodynamics to convince and make students understand the basics concepts of thermodynamics especially the concepts of entropy and Second Law of Thermodynamics which seems to student as abstract things [5-8]. There are many approaches being applied and used by dedicated educators in order to gain students' interests to learn thermodynamics. These include using simulation programmes to perform virtual experiments to promote understanding of the abstract thermodynamics concepts [5, 6]. Haglund and Jeppsson [9] used self-generated analogies to introduce abstract concepts in teaching thermodynamics. This approach allows students to learn a new object of study, a target domain, by comparing with a more familiar source domain. El-Awad and Elseory [10] have introduced the application of Microsoft Excel to develop computerised tables that can automatically determine the thermodynamic properties. Due to the increasing and rapid usage of ICT nowadays, Nancheva et al. [11] has explored the teaching of thermodynamics through a web-based application.

In the Department of Chemical and Process Engineering, UKM, two programmes are offered: Chemical Engineering Programme and Biochemical Engineering Programme. The curriculum for both programmes requires first year students to undertake two consecutive compulsory courses on thermodynamics. For Semester I, the students should attend KKKR1134 Chemical Engineering Thermodynamics I and KKKR1244 Chemical Engineering in the Semester II. The basic concepts f thermodynamics is covered under KKKR1134 and the second thermodynamic course, KKKR1124 covers the phase equilibrium and solution thermodynamics for pure and multicomponent mixtures. The KKKR1134 course exposes first-year chemical engineering students to the basic concepts of thermodynamics such as the properties of pure substances, the first law of thermodynamics, entropy and the second law of thermodynamics and on the thermodynamic applications of power and refrigeration cycles. The syllabus covers the First Law and Second Law of Thermodynamics and how these two laws are applied on closed systems and control volumes (Fig. 1). Students should grab the understandings of the principles of these two laws and know to apply these two laws on the two different types of systems since each system requires different approach to apply the two laws as illustrated in Fig. 1. Before the two laws can be applied, students should acquire the skills to obtain relevant data from property tables such as Steam Table or property diagrams.

Table 1 lists the six course outcomes that students should achieve at the end of a semester for KKKR1134 course. All COs except CO2 are the skills and attributes that can be achieved through lectures. CO2 is the course outcome to be acquired through laboratory works regarding temperature and pressure measurements. CO1 requires students to understand some definitions of thermodynamic terms such as temperature, pressure, system, property, states, cycles and equilibrium. All these thermodynamic terms will be used and encountered throughout the syllabus. Subsequently, students should be able to identify the properties of substances on property diagrams and obtain the data from property tables (CO3). Without this skill, students fail to proceed solving any thermodynamic problem although they understand how to apply the two laws. CO4 illustrates the students how the energy can be transferred through a system boundary. Once the students gain this attributes, they should know how to apply the First Law of Thermodynamics on closed and control volume systems (CO5). Finally, the concept of entropy and the Second Law of Thermodynamics will be introduced and used in analysing the thermal efficiencies of heat engines such as Carnot and Rankine cycles and the coefficients of performance for refrigerators (CO6).

Table 1. List of Course outcomes (COs) for the course of KKKR1134 Chemical Engineering Thermodynamics I.

No.	Course outcomes (COs)
CO1	Ability to understand the basic concepts of thermodynamic such as temperature, pressure, system, properties, process, state, cycles and equilibrium.
CO2	Ability to conduct experiments regarding the measurement and calibration of temperatures and pressures in groups.
CO3	Ability to identify the properties of substances on property diagrams and obtain the data from property tables
CO4	Ability to define energy transfer through mass, heat and work for closed and control volume systems.
CO5	Ability to apply the first Law of Thermodynamics on closed and control volume systems.
CO6	Ability to apply Second Law of Thermodynamics and entropy concepts in analysing the thermal efficiencies of heat engines such as Carnot and Rankine cycles and the coefficients of performance for refrigerators.

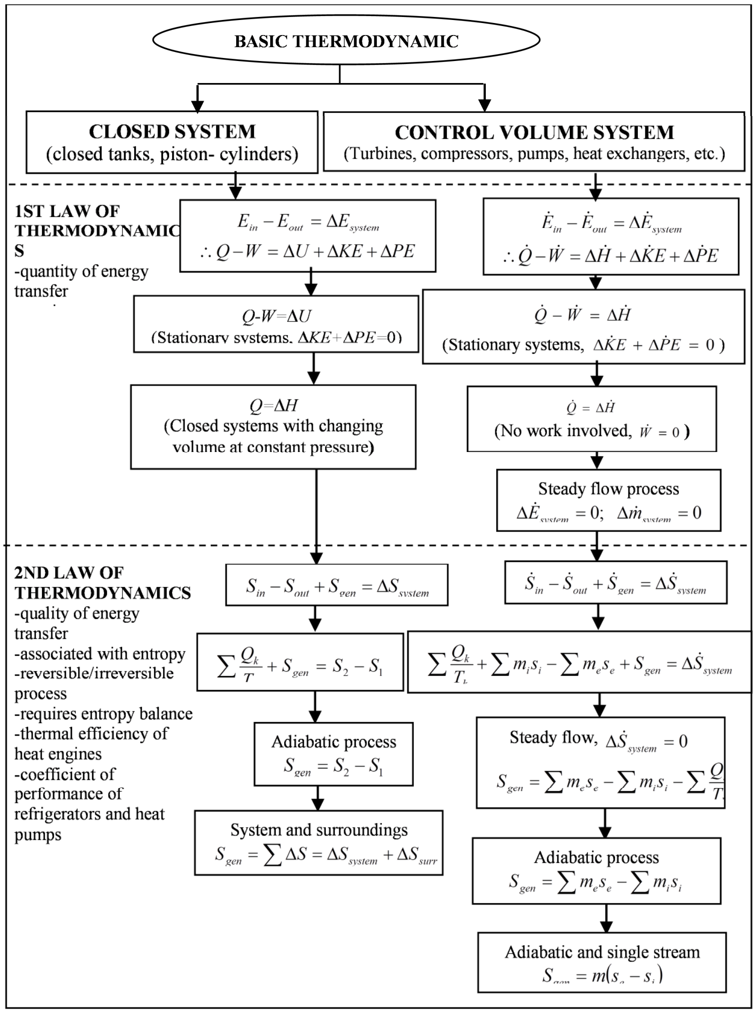

Fig. 1. Summary of the syllabus covered in KKKR1134 Chemical Engineering Thermodynamics I.

3. Research Methodology

In order to improve the quality of the teaching and learning process for the fundamentals of thermodynamic course, a course evaluation through an indirect measurement was conducted by distributing a questionnaire to the first year students of Chemical Engineering Programme in the Department of Chemical and Process Engineering, UKM, who has attended KKKR1134 Chemical Engineering Thermodynamics I in Semester I Session 2012/2013. The questionnaire was distributed to 22 students on week 11 of a 14-week lecture time, after the entire course syllabus has been completely covered. The questionnaire was designed in such a way that the students are required to give their feedbacks on the achievement of the six outlined course outcomes (Table 1) at the beginning of the semester as well as at the end of the semester according to a Likert scale as listed below:

Scale 0	No idea
Scale 1	Know specific facts, terms, concepts, principles or theories
Scale 2	Understand and able to interpret specific facts, terms, concepts, principles or theories
Scale 3	Able to apply related theories to new situations and able to solve related problems
Scale 4	Able to use the related knowledge and theories to design a chemical or biochemical engineering system
Scale 5	Able to use the related knowledge and theories to analyse and evaluate a chemical or biochemical engineering systems

These scales are arranged according to 5-tier Bloom's Taxonomy of cognitive learning skills [12]. All the feedbacks obtained from the questionnaire on the course outcome achievement will be converted in terms of average marks, to be compared with direct measurement of course outcome achievement by students through mid-semester and final examinations, laboratory work, quizzes and integrated project.

The results were analysed using an independent samples T-test with significant difference of probability was set to below than 0.05 ($p<0.05$). Statistical calculations were executed with IBM SPSS Statistics software for Windows, version 21 (SPSS Inc. USA).

4. Results and Discussion

Figure 2 compares the students' feedbacks from the distributed questionnaire (indirect measurement) on the achievement of the six course outcomes with the marks obtained by students through direct measurement of mid-semester and final examinations, laboratory work, quizzes and integrated project for the two programmes (Chemical Engineering Programme and Biochemical Engineering Programme). At the end of the semester, the feedbacks from the students (indirect measurement) indicated that most students have grabbed some understandings on the basic concepts and shown the ability to use and apply the two laws. On average, Chemical and Biochemical Engineering students felt that they were able to achieve the outcomes at a level of 60% and 70% respectively.

When compared to the student scores obtained from the direct measurement of examinations, quizzes, laboratory and integrated project, all the achievement of the outcomes through indirect measurement are significantly higher for both programmes except for CO2 which deals with the laboratory skills. Students felt that they could achieve the course outcomes confidently, but when comes to the examinations, quizzes and project, their performance were lower from what they have expected. For Chemical Engineering students, the achievement of COs through direct and indirect measurement are not significantly different, giving evidence that the students could understood the theory on the first law of thermodynamics very well and know how to apply it on closed systems and control volumes very confidently. On average, the Chemical Engineering students scored 53% on the achievement of the outcomes which is equivalent to Grade B-, while the Biochemical Engineering students scored 41% (equivalent to Grade C-). On overall, the performance of students through examinations, quizzes and integrated project are still not satisfied. The findings from this comparative study can be used by the lecturer to further improve the delivery methods on the course and to convince students that this course is not a tough subject as inherited from generation that this subject as a “killer subject” among the students [6, 12]. The course can be enjoyable by always relating the application of First and Second Law of Thermodynamics in daily lives.

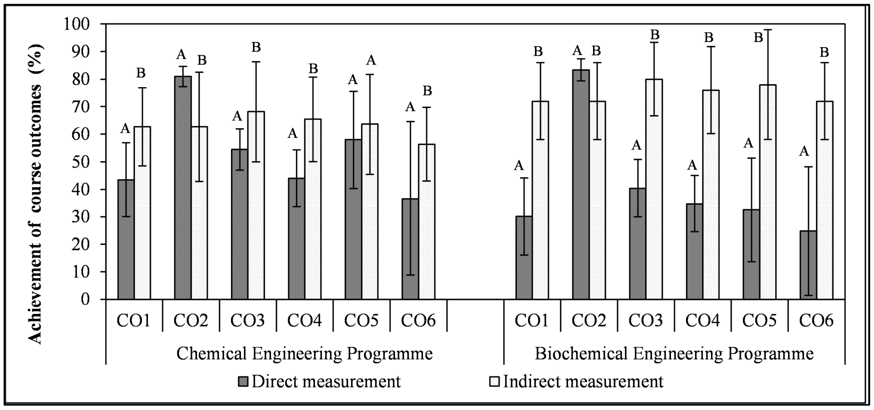

Fig. 2. Comparative analysis of the achievement Of Course Outcomes For KR1134 Chemical Engineering Thermodynamics I through direct and indirect measurement for Chemical and Biochemical Programmes (Different letters (A, B) show statistically significant difference between direct and indirect measurements (p<0.05)).

5. Conclusions

For the improvement of teaching and learning in basic concepts of thermodynamics course, a survey on the achievement of the course outcomes was distributed to the first year students in the Department of Chemical and Process Engineering, UKM. Based on the feedbacks from the survey, students have shown confidence in the achievement of the six course outcomes at the end of the semester. However, the performance of students through examinations, quizzes and integrated project are not following the same trend as in the indirect measurement completely. Lectures who handle the course should always have the effort and initiatives to further improve the delivery of the course.

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