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### THE DEVELOPMENT OF A MICROCOMPUTER-BASED LABORATORY (MBL) SYSTEM FOR GAS PRESSURE LAW EXPERIMENT AND THE PERCEPTION STUDY

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# DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF EDUCATION (PHYSICS)

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# DECLARATION

I hereby declare that the work in this dissertation is my own except for quotations and summaries which have been duly acknowledged.

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### ABSTRAK

Tujuan kajian ini adalah untuk membangunkan satu sistem pembelajaran makmal berasaskan komputer (MBL) bagi eksperimen Hukum Fizik Tekanan Gas di peringkat Pendidikan Tinggi. Kajian ini dibahagikan kepada 2 bahagian; bahagian pertama melibatkan pembangunan sistem dan bahagian kedua ialah kajian persepsi terhadap penggunaan sistem yang telah dibangunkan. PHOENIX (Pengelog Data) adalah perkakasan utama dalam sistem ini yang diperoleh dari Inter-University Accelerator Centre (IUAC), New Delhi. Perkakasan lain yang digunakan ialah penderia suhu dan penderia tekanan. Perkakasan tersebut dikawal oleh komputer. Penderia ini ditentukur selaras dengan piawaian tekanan dan suhu. Data dan parameter yang diperolehi daripada penentukuran digunakan dalam koswer untuk menentukan nilai tekanan dan suhu berdasarkan voltan penderia itu. Rekabentuk koswer untuk sistem ini berasaskan model instruksional Analysis, Design, Development, Implementation, and Evaluation (ADDIE), sementara pengaturcaraan koswer menggunakan Bahasa Python (salah satu Perisian Terbuka). Koswer ini menyediakan satu eksperimen bagi Hukum Gay-Lussac (Hukum Tekanan). Eksperimen ini mengukur perubahan tekanan dan suhu gas dalam satu kelalang Erlenmeyer. Koswer ini memaparkan data pada skrin komputer melalui graf. Bahagian kedua adalah kajian yang dijalankan ke atas 41 responden terdiri daripada pelajar yang mengambil subjek termodinamik bagi menjalankan latihan eksperimen dengan menggunakan sistem yang dibangunkan. Aspek persepsi meliputi antaramuka pengguna, paparan graf, penggunaan perisian, pemasangan perkakasan dan nota panduan. Analisis data menggunakan kaedah statistik diskriptif dengan lima skala Likert. Skor purata min 4.01 diperolehi daripada dapatan kajian. Ini menunjukkan koswer berpretasi baik. Penggunaan koswer boleh dikembangkan untuk pengajaran dan pembelajaran bagi pelbagai peringkat pengajian.

#### ABSTRACT

The purpose of this research was to develop a Microcomputer-Based Laboratory (MBL) system for gas pressure law experiment used in tertiary physics education. The research was divided into two parts; the first part was to develop the system and the second part was to study the perception towards the use of the built system. The main hardware of the system was the PHOENIX (Data Logger) which was obtained from Inter-University Accelerator Centre (IUAC), New Delhi. Others hardware used were temperature sensor and pressure sensor. These hardware components were controlled by a computer. The sensors were calibrated according to the standard reference of pressure and temperature. The data and parameters obtained from the calibration were used in the courseware to determine the pressure and temperature based on the voltage of the sensors. The courseware design for this system was developed based on the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional model, while the courseware programming was written by using the Python Language (one of the Open Source Software Systems). This courseware provided an experiment for the Gay-Lussac's Law (Gas Pressure Law). This experiment measured the change of pressure and temperature of the gas in the Erlenmeyer flask. The courseware was able to display the data in the form of graph on the computer screen. The second part of the study was conducted on 41 respondents who joined the thermodynamics course to run the laboratory exercise using the built system. The perception aspects studied were user interface, graph display, use of courseware, installation of hardware and guide note. The data analysis was done by using descriptive statistics with the five-point Likert scale. An average mean score of 4.01 was obtained from the result. This shows the courseware has good performance. The application of this courseware can be expanded in the teaching and learning for other level of education.

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#### LIST OF PUBLICATIONS

#### **Conference** Publication

"Development of Microcomputer-Based Laboratory (MBL) System for Gas Law Experiment Using Python Programming", presented at National Colloqioum "National Postgraduate Colloqioum on Science & Mathematics 2009" 21 December 2009, Malaysia. (Speaker)

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#### Exhibition

"Open Source-Based Gas Law Experiment for Physics Education" presented at International Exhibition "9<sup>th</sup> Malaysia Technology Expo (MTE 2010)", 04 - 06 February 2010, Putra World Trade Centre (PWTC), Kuala Lumpur, Malaysia. (Exhibitor)

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# LIST OF ABBREVIATIONS

ADDIE: Analysis, Development, Design, Implementation and Evaluation

- DC : Direct Current
- ICT : Information Communication Technology
- ISD : Instructional Systems Design
- IUAC : Inter-University Accelerator Centre
- MBL : Microcomputer-Based Laboratory
- OS : Operating System
- OSS : Open Source Software
- PMDK: PHOENIX Micro-controller Development Kit
- RTD : Resistance Temperature Detector
- SD : Standard Deviation
- Tk : Tkinter (GUI toolkit for Python)
- UI : User Interface
- UPSI : Sultan Idris Education University (Universiti Pendidikan Sultan Idris)
- USM : Universiti Sains Malaysia

# CHAPTER 1

#### INTRODUCTION

This chapter begins with the Microcomputer-Based Laboratory (MBL) system and its application. This chapter also discusses the research background, problem statements, research objectives, research questions, significance of the research, limitation and delimitation of the study. This is followed by the definitions of terms, framework of the study and summary of the chapter.

### 1.1 MBL System and Its Application

Generally, the MBL system can be divided into two major parts; hardware and software. The hardware part consists of data logger and various types of sensors. The

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UNIVERSITI software part is to execute data logging, data processing and display the real-time plot on the computer screen.

> Scientists need experiments to verify theories. For students, they need to do the experiments in order to understand the theories. So, the experimental exercises are very important in learning physics. MBL system is one of the practical approaches to run the experiments. However, the MBL hardware and software in the market are very expensive for school, matriculation, college and university laboratories in Malaysia.

> For the thermodynamics course, there are many experiments which require the use of thermometers and bourdon gauges. Additionally, the students need to take both readings at same time. Therefore, this manual data collection will produce errors. So, it is totally different if the students use the MBL system. The MBL system enables the user to gather both data simultaneously. For these reasons, researcher developed a low-cost MBL system using a data logger incorporated with the temperature and pressure sensors. The courseware program for controlling the system was written by using the Python Programming Language version 2.4.3 (one of the Open Source Software System).

#### 1.2 **Research Background**

Conventional practical exercises in learning Physics normally require students to follow specific procedures and solve specific questions provided in the laboratory

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UNIVERSITI Pmanual. Hence, longer period of time is used to conduct these routines of recording the data manually, plot the graph and doing the data analysis.

In the MBL system, all routine jobs are computerised and therefore save the time for other activities. The MBL activities can be programmed as to encourage students to create questions and solve the problems themselves, instead of depending on the limited scope of the questions provided in the laboratory manual (Krajcik and Layman, 1993).

To use the MBL system, the students need to fix or probe sensors to a system. The probe is attached to a computer, where it provides utility for students to access the instruction and information displayed. Students will have the opportunity to perform a real experiment and compare to simulation experiment. Hence, they will gain new learning experience in performing experiment by using the MBL system. Students will be able to collect and record data and then plot the graph immediately on the monitor screen of the computer.

Since the MBL activities can be diversified, the teachers who develop the experiments will also increase the knowledge and creativity in developing new experiments. As Steinberg (2003) claimed, "science teachers who progressively upgraded the MBL technique, which could attract students' attraction, would have the opportunities to engage students intellectually, to explore more meaningful and exciting subject matter".

Generally, the cost for the MBL system development and the use of the MBL

apparatus is relatively higher than the cost for the conventional manual system. The cost will be even higher if the system is to be applied in all stages of education (Gintautas and Hubler, 2009; Ajith Kumar, 2008). In order to make it possible for the MBL system to be used in education, the cost must be cut down. A group of workers from the Inter-University Accelerator Centre (IUAC) had taken up this task. They developed the PHOENIX Development System for Designing Science Experiments. This hardware package was cheap enough for college level or even school laboratories to own and enabling them to do experiments and performed numerical analysis of the data using computers (Ajith Kumar, 2008). To make it cheaper, the software development for package uses the Python Programming Language from the Open Source Software (OSS) system.

OSS system offers free access and paid access with affordable pricing. This offer leads to the foundation of the Malaysian Public Sector OSS Master Plan (OSCC Malaysia, 2007) which aims to reduce total cost paid for the ownership and increase freedom of choice of the software usage. The master plan includes the development, implementation and roadmap to establish an Open Source Competency Centre (OSCC) which runs the OSS application in the administration of the Public Sector.

In line with the country's aspiration, researcher used the python programming language for software development in this project. Python programming language is available on the website and it can be easily downloaded.

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The annoyances of errors in scientific experiments are unavoidable but the errors can be reduced. In the conventional experiment for thermodynamics, there are two types of errors. The first type is the random errors which are due to incorrect eye position of the observer or incorrect instrument when making measurement. The second type is the systematic errors which are due to the error in calibration of instrument or imperfect methods of observation (Northrop, 2005). The students will find out the overall errors after comparing the experimental result with theoretical result. The students will have to repeat the whole process of the experiment in order to have more precise result.

For example, Figure 1.1 shows the Pressure Law experiment for secondary school in Malaysia (Chang, Koay Kheng Chuan & Yew Kok Leh, 2007). The aim of the experiment is to investigate the relationship between the pressure and temperature of gas when volume is constant. However, the thermometer measures the temperature of water. This will generate the systematic error. While reading the data from the thermometer or bounder gauge, the students may get incorrect data due to incorrect eye position (random error). Additionally, they need to gather both readings; the temperature and pressure simultaneously.

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Figure 1.1 Conventional Pressure Law Experimental Setup

The MBL system can overcome the difficulties faced in the conventional way of performing the gas pressure law experiment. The random errors can be reduced because the data are recorded by temperature and pressure sensors. The systematic error is corrected because these sensors are placed in the gas system. Nevertheless, the standard MBL system and apparatus available in the market are foreign products and they are expensive (Taylor, 1997; Ajith Kumar, 2006; Gintautas and Hubler, 2009). The software to run the experiments remains the property of the manufacturer and cannot be accessed. So, the application cannot be diversified. The component parts and servicing are all depending on the manufacturer alone which causes delay and high maintenance cost. Those problems are summarised and listed below:

- 1. Random error which is due to incorrect eye position of the observer.
- 2. Systematic error which is due imperfect methods of observation.
- 3. The data of pressure and temperature cannot be recorded simultaneously.
- 4. The cost of MBL system in the market is too expensive.

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The main purpose of the research is to develop a Microcomputer-Based Laboratory (MBL) System in Gas Pressure Law Experiment for Tertiary Physics Education. Then, a study on students' perception through the use of the apparatus was carried out. The development includes the calibration of sensors, courseware development, designing of the complete Gas Pressure Law experimental set and the application of the system (hardware and courseware) for the Gas Pressure Law experiment. The system adopts the technology of the PHOENIX (Data Logger) from IUAC and incorporates with specific sensors. The process of the experiment is controlled by a computer. Courseware development is done by using the Python Programming Language which is one of the Open Source Software (OSS) systems. In order to achieve these goals the objectives of this research are listed below.

- To develop a MBL system incorporating the technology of PHOENIX (Data Logger), pressure sensor, temperature sensor and the courseware package developed by using the Python Programming Language.
- To design a complete experimental set (Gas Pressure Law) for use in the thermodynamics course.
- 3. To validate the complete experimental set (Gas Pressure Law) for use in the thermodynamics course.
- 4. To study the students' perception on the complete MBL experimental system.

The focus in this research is the development of a complete MBL experimental set for the Gas Pressure Law experiment. The development is followed by a perception study on the use of the MBL experimental set. The outcomes of the survey are expected to provide answers to the following questions:

- 1. Do the respondents have the prior experience in performing the Pressure Law experiment in the secondary school?
- 2. What are the perceptions of respondents about the design of MBL package?
- 3. What are the difficulties experienced by respondents who use the experimental apparatus?
- 4. What are the weaknesses of the MBL package?
- 5. How can respondents' perceptions be used to improve the MBL package?

#### **1.6** Significance of the Research

The built MBL system is meant to be used for laboratory exercises in UPSI. It is because the gas pressure law experiment in university still using the conventional method. The quantities (pressure and temperature) were observed and recorded manually.

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UNIVERSITI PEN This hardware is relatively cheap. The components are available in our local suppliers. Schools and colleges can get these materials easily within reasonable short time. However, the teachers and instructors need to study, modify and develop the experimental set to suit their laboratory exercises and also learn to understand the development of the courseware.

On a large scale, this idea will be accepted by the government authorities to improve teachers' attitude towards exploring new knowledge in this MBL package (hardware and courseware development) for teaching and learning in science. At the same time, the science laboratory facilities in school and universities can be upgraded from time to time.

#### **1.7** Limitation and Delimitation

The respondents of the study were limited to the undergraduate students who were taking the course TFA-2043 Thermodynamics, Physics Departments, UPSI. Therefore, the result cannot be used to generalize the perception of tertiary students at large which should include students from other universities and tertiary institutions.

The scope of the hardware used in the research was delimited to the use of only 2 types of sensors (pressure and temperature sensors). The delimitations include the range of the pressure sensor between 20 - 250 kPa. Additionally, the result and

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VIDRIS UNIVERSITATISCUSSION will be focussed only on the Gas Pressure Law experiment. The Boyle's IS UNIVERSITI Law and the Charles's Law are excluded.

#### 1.8 Definitions of Terms

The following terms were used throughout this study and are defined as follows:

- Microcomputer-Based Laboratory System the integration of computer hardware and software in the form of the interfaces and sensors for use in the science laboratory (Tomshaw, 2006). Widjaja (2002) defined the Microcomputer-Based Laboratory (MBL) as a device design to collect the data via various probes, which detect physical quantities and then store the data in the computer. In this study, the pressure and temperature sensors are used in the gas pressure law experiment.
- 2. Gas Law Experiment gas law experiments are to investigate the relationship among pressure, volume and temperature of a gas (Young and Freedman, 2004). In this study, the dependence of pressure on temperature was investigated. The pressure temperature relationship (for constant volume) is called the Gay-Lussac's Law (Gas Pressure).