Electro pneumatic trainer embedded with programmable integrated circuit (PIC) microcontroller and graphical user interface platform for aviation industries training purposes

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Abstract. An electro pneumatic trainer embedded with programmable integrated circuit (PIC) microcontroller and Visual Basic (VB) platform is fabricated as a supporting tool to existing teaching and learning process, and to achieve the objectives and learning outcomes towards enhancing the student’s knowledge and hands-on skill, especially in electro pneumatic devices. The existing learning process for electro pneumatic courses conducted in the classroom does not emphasize on simulation and complex practical aspects. VB is used as the platform for graphical user interface (GUI) while PIC as the interface circuit between the GUI and hardware of electro pneumatic apparatus. Fabrication of electro pneumatic trainer interfacing between PIC and VB has been designed and improved by involving multiple types of electro pneumatic apparatus such as linear drive, air motor, semi rotary motor, double acting cylinder and single acting cylinder. Newly fabricated electro pneumatic trainer microcontroller interface can be programmed and re-programmed for numerous combination of tasks. Based on the survey to 175 student participants, 97% of the respondents agreed that the newly fabricated trainer is user friendly, safe and attractive, and 96.8% of the respondents strongly agreed that there is improvement in knowledge development and also hands-on skill in their learning process. Furthermore, the Lab Practical Evaluation record has indicated that the respondents have improved their academic performance (hands-on skills) by an average of 23.5%.

1. Introduction

Graphical User Interface (GUI) has become one of the potential tools in teaching and learning process, especially in engineering discipline for better understanding of complexity in engineering processes. The students have the opportunity to engage in active learning environment by conducting simulated experiments, gathering results, collecting data, drawing conclusions and troubleshooting. Furthermore, GUI or computer simulation can enhance the student’s active involvement in teaching and learning process [1]. Computer simulations such as Electronics Workbench, LegoCAD and Car Builder help trainees to understand events, processes and activities that can be replicated into real world problems. Besides that, it engages the students with activities that are equal to the real-life hands-on laboratory experiences effectively [2]. This contributes towards greater understanding and skill enhancement as compared to typical teaching and learning process (chalk and talk).
PIC that belongs to the microcontrollers family is manufactured by Microchip Technology Inc., the leading microcontroller and analogue semiconductor manufacturer. Microcontroller is essentially a microprocessor that is equipped with Input/Output (I/O) circuitry and built-in peripheral, allowing for direct interface with real-world devices such as switch, pneumatic solenoid, motors, sensors and other devices [3]. PIC simplifies the design of logic and control system, permitting the design of complex behaviour to be embedded into a piece of electronics instruments. Meanwhile, an understanding on embedded system is an area of study that requires more in-depth exposure so as to meet the global industry’s needs [4, 5].

The role of control engineering discipline in the polytechnic education and aviation industries is very significant. Competent aviation’s technician, semi-skill trained technician or technical manpower is trained in programs offered at Electrical Engineering Department, Polytechnic Sultan Salahuddin Abdul Aziz Shah (PSA) and Aircraft Maintenance Engineering Department, Polytechnic of Banting Selangor (PBS). Students should receive hands-on experience with the support of simulation and real devices. It is anticipated that there is better demand and wider job opportunities for technical graduates who are exposed to, and understand electro pneumatic control and embedded principles [6]. Hence, teaching and learning need to be supported with more advanced hands-on experiences and graphical simulations in order to make the learning more interesting and helpful compared to typical classroom method.

The aviation industries involve huge number of electro pneumatic devices that are used in aircraft system such as pneumatic actuator for moving the flight control surfaces, spoiler control, pneumatic actuator for landing gear of small aircraft, de-icing boot for small and older aircraft, etc. The need to produce competent aerospace/aircraft technician is vital for the future safety of aircraft manufacturer, line maintenance and airline operators. Better understanding of knowledge and higher opportunities for hands-on training for the aircraft technicians will help to minimize aircraft catastrophes caused by human errors [7]. The booming aviation industries stress on production of skilled aviation technicians or engineers with hands-on experience to meet the demands from aviation industries. Unfortunately, not many education providers or institutions are well equipped to produce these competent aviation technicians or engineers. As a matter of fact, there is also a lack of aviation institutions that could produce quality, competent and experienced trainees to meet the industries’ needs [8]. As such, it is hoped that these ‘issues’ could be resolved with the introduction and usage of enhanced teaching aids such as the electro pneumatic trainer in the teaching and learning process of the students.

The development of this electro pneumatic trainer is focused on students studying Instrumentation (DEJ 3143), Pneumatic System (DEA 4043) for Diploma in Electronics (Control) at PSA and also Pneumatic and Hydraulic (DWM 4302) courses for Diploma in Aircraft Maintenance at PBS. It is also useful for other related programs offered in the Malaysian polytechnics system [9]. The development also helps to meet the demands from other aviation training institutions that produce competent and skilled human resources needed by the aviation maintenance organisations as forecasted by relevant bodies [10].

2. Execution of existing electro pneumatic course

Learning is best conducted when teaching and learning is focused on simulation, hands-on experiences with real instrument, machines or in automation system [11]. During the establishment of Sultan Salahuddin Abdul Aziz Shah Polytechnic in 1997 and Banting Polytechnics in 2012, there was no suitable device prepared for teaching and learning. The students had to relate to the theory they learned in the classroom with experimental activities by using the individual electro pneumatic apparatus only. The apparatus need to be wired individually in order to trigger the operation of the devices as shown in Figure 1. For instance, students need to connect the air supply to the air motor in order to operate the motor and disconnect the air supply to stop the air motor operation. The existing method involves high risk because students have to deal with the 240 VAC motor switches frequently to manually operate the air motor. No wiring connection is available between two or more apparatus such as semi rotary motor and air motor, and this needs to be tested individually and manually. Furthermore, there is no
graphical simulation available before the students can conduct the hands-on lesson during the teaching and learning process. Besides that, aviation industries also require more skilled personnel with hands-on experience dealing with real devices [12]. Nowadays, the aviation industries require more skilled workers that can operate real devices. In order to achieve this aviation industry demand, educational sector needs to be aware and come out with more practical courses that can equip the students with more hands-on skills.

This electro pneumatic trainer is embedded with PIC and VB, and it is fabricated based on the problems encountered by lecturers and students at the Electrical Engineering Department, Sultan Salahuddin Abdul Aziz Shah Polytechnic and Banting Polytechnic, and also the aviation industrial needs. Studying electro pneumatic courses is best when applied with simulation and hands-on work. Facilities at Electrical Engineering Department are unable to meet the practical requirement outlined in the educational syllabus. With regard to this, lecturers often face problems in complying with syllabus requirement and meeting industrial needs. The existing approach also does not enhance the students’ apparatus wiring and programming skills. The use of VB and PIC in teaching is considered vital as currently, there is limited equipment that can be used by students for gaining knowledge and hands-on skills [13]. Most trainers in the market can hardly meet the requirement of the syllabus. Moreover, the existing technique only applies a minimum hands-on wiring skill and students are assessed at low level of competency. There is a great need to reform the teaching methods and assessment tools, laboratory equipment and experiments, in enhancing students’ hands-on skills and practical ability, laying a good foundation for their future job, and improving their social competitiveness and the quality of personnel training [14]. In light of this deficiency, this innovation is designed and fabricated to meet the overall objective in enhancing knowledge and hands-on skill for electro pneumatic courses and introducing various types of output apparatus to a trainer.

3. Overall system process and design requirement for electro pneumatic trainer

At preliminary stage, it is required to come up with the overall process and design requirement for the electro pneumatic trainer. Figure 2(a) shows the flow chart of the overall system process meanwhile Figure 2(b) shows the designed requirement and the sequence step for the start-up and troubleshooting process for the electro pneumatic trainer. There are some criteria that need to be considered prior to the overall design requirement – attractive design (to attract the students’ attention during the teaching and learning session), effective (more integration of output components compared to the availability of the trainer in market) and user friendly (easy for installation and use by instructor and trainees during the teaching and learning and hands-on session). This consideration will be looked into in driving the designing stage prior to the actual execution and fabrication of the trainer.

First stage is the fabrication of PICs interface circuit, which provides analogue and digital series of input and output that can be used to control the electro pneumatic trainer. The block diagram of PIC circuits as interface to control the electro pneumatic apparatus is shown in Figure 3. It consists of PIC module, input section, output section and power supply. The input section is controlled through GUI programming (VB platform) while output section consists of one unit of air motor, one unit of single acting cylinder, one unit of double acting cylinder, one unit of semi rotary air motor and one unit of linear drive. The microprocessor used in this circuit fabrication is 40-pin PIC16F877A.
Figure 2. (a) Flow chart for the overall system process, (b) design requirement and sequence of trainer usage
4. Building the electro pneumatic trainer

Power supply distribution for electro pneumatic trainer is as shown in Figure 4. From the 240VAC power supply to power-up the air compressor unit, the wiring is then reduced to 12 VDC for electro pneumatic apparatus and lastly 5 VDC for PIC interface board and relay unit. The fabrication process of this electro pneumatic trainer is divided into three main stages: arrangement of electro pneumatic apparatus, PIC module (interface) and GUI (VB programming) as shown in Figure 5.

![Block diagram for PIC control of electro pneumatic apparatus](image)

**Figure 3.** Block diagram for PIC control of electro pneumatic apparatus

![Power supply distribution for electro pneumatic trainer](image)

**Figure 4.** Power supply distribution for electro pneumatic trainer

![Stages of electro pneumatic trainer fabrications](image)

**Figure 5.** Stages of electro pneumatic trainer fabrications

C code was used in programming the PIC through MPLAB since it is the assembly (or assembler) language (ASM). Figure 6(a) shows the compiled code for programming the electro pneumatic trainer while Figure 6(b) shows schematic diagram for PIC interface circuit. USB cable was used to download the HEX code generated by compiler from computer to PIC microchip when the programming process completed. Visual Basic 6.0 was used as the graphical user interface (GUI) input to trigger the output (electro pneumatic apparatus). If the user clicks ‘ON’ (HOLD) switch for a single acting cylinder, the
The actual single acting cylinder apparatus will expand and when releasing ‘ON’ (HOLD) switch the actual single acting cylinder will return to its original position. Same operation goes on when each of the ‘buttons’ acting as switches on VB display is clicked as shown in Figure 7.

![Figure 6](image6.png)

**Figure 6.** (a) Programming code of PIC 16F877 using MPLAB platform, (b) Schematic diagram of PIC interface board

![Figure 7](image7.png)

**Figure 7.** VB (input) display controlling the electro pneumatic (output) apparatus

### 5. Implementation and measurement stages

In order to measure the enhancement of knowledge, hands-on skills, and layout of the newly fabricated electro pneumatic trainer, a questionnaire will be distributed to selected respondents. The criteria for selection of respondents are based on the requirement to undergo for related electro pneumatic courses, they have electrical engineering background and they have had direct hands-on experience with the newly fabricated Electro Pneumatic Trainer. Four classes from the Electrical Engineering Department, DJK 3A, 3B, 3C and 3D that have completed the *Instrumentation* (DEJ 3143) lab course were selected as respondents. Before the questionnaires were distributed to the respondents, they need to accomplish the required hands-on practical. They need to complete existing hands-on practical (manual connection of individually apparatus) and continued with using the newly fabricated electro pneumatic trainer. 

#### Table 1. Total number of respondents

| Course Name         | Programme Name                | Class | No. of Students |
|---------------------|--------------------------------|-------|-----------------|
| Instrumentation     | Diploma in Electrical Engineering | DJK 3A | 43              |
| (DEJ3143)           | (Control)                      | DJK 3B | 45              |
|                     |                                | DJK 3C | 45              |
|                     |                                | DJK 3D | 42              |
| **TOTAL**           |                                |       | **175**         |
Table 2 displays the summary of the distributed questionnaire. It was separated into two different sections: Section A is to measure the hardware and simulation section of the electro pneumatic trainer whereas Section B is to gauge the knowledge and also hands-on skill of the respondents. Section A includes three main questions regarding the attractiveness, safety and user friendliness while Section B includes eight questions, mainly on understanding, hands-on skill improvement, critical thinking and interest.

Table 2. Summary of finding for execution of electro pneumatic trainer

| No. | Items                                                                 | Frequency | Yes (%) | No (%) |
|-----|------------------------------------------------------------------------|-----------|---------|--------|
|     | **Section A: Hardware and VB development for Electro Pneumatic Trainer** |           |         |        |
| 1   | It is easy to use the trainer during hands-on because it is user friendly. | 170       | 97.1    | 2.9    |
| 2   | Are safety features emphasized in the newly developed trainer?         | 171       | 97.7    | 2.3    |
| 3   | Various apparatus of electro pneumatic on this trainer attracts me to study about Control System. | 169       | 96.6    | 3.4    |
|     | **Average (%)**                                                        |           | 97.1    | 2.9    |
|     | **Section B: Knowledge and Hands-on skill**                            |           |         |        |
| 1   | My understanding on control of electro pneumatic apparatus (input and output devices) is enhanced. | 169       | 96.6    | 3.4    |
| 2   | It is easy to understand the connection from input to output.         | 172       | 98.3    | 1.7    |
| 3   | Using this trainer can enhance the understanding on electro pneumatic courses. | 168       | 96.0    | 4.0    |
| 4   | My wiring skill in connecting the electro pneumatic apparatus is improved. | 170       | 97.1    | 2.9    |
| 5   | Hands-on experience by using this trainer can provide some ideas for my Final Year Project (FYP) | 165       | 94.3    | 5.7    |
| 6   | Using this trainer can enhance my hands-on skills                      | 170       | 97.1    | 2.9    |
| 7   | My interest in learning about electro pneumatic is enhanced when using this trainer. | 169       | 96.6    | 3.4    |
| 8   | It is easy to understand the theoretical part when using this trainer. | 172       | 98.3    | 1.7    |
|     | **Average (%)**                                                        |           | 96.8    | 3.2    |

From the questionnaires, it shows that majority of the respondents are satisfied with the hardware fabrication and simulation development for electro pneumatic trainer. About 97% of the respondents agreed that it is user friendly, attractive and safe during the execution of the hands-on practical. The electro pneumatic trainer is considered attractive as more students give attention during the teaching and learning process, and also during the hands-on session (Section A: Item 3: 96.6%). It is also more effective because additional integration of various output components is embedded in this trainer as to uphold the curriculum requisite (i.e. five different output components). Furthermore, it is also user friendly because it is easily installed and operated by the instructor and students during the teaching and learning, and hands-on session as indicated in the survey.

Meanwhile, 96.8% of the total respondents agreed that the newly fabricated trainer enhanced their knowledge and hands-on skill in learning electro pneumatic courses. This indicates a good preparation
for the students before entering real-work environment. 94% of the respondents also agreed that it would enhance their critical thinking in early preparation for their final year project (FYP).

The overall cost for the development of this Electro Pneumatic Trainer was MYR 350 per trainer and this includes fabrication of the interface module and input module (VB platform) only. There are some recycled components that were used in this development such as the output module (i.e. double acting cylinder, single acting cylinder, air motor, semi rotary motor and linear drive) and the air compressor machine. This is cost effective in enhancing the teaching and learning process since the institution only needs to invest a very minimum amount for the production of this trainer. If the training institution wants to produce the same computer simulation and hands-on training apparatus, they need to purchase the software and hardware with an average cost between MYR 10,000 to MYR 25,000 as market price. Luckily, with the implementation of this newly developed electro pneumatic trainer, the cost is already reduced by using available expertise and materials. Table 3 and Table 4 compare the respondents’ outcome based (students’ performance) on identical practical’s tasks that has been assigned using the manually connected electro pneumatic apparatus method as well as using the newly developed Electro Pneumatic Trainer.

Table 3. Respondents’ marks using manually connected electro pneumatic devices

| CLASS  | Tubing connection (25%) | Solenoid valve connection skill (25%) | Discussion (20%) | Conclusion (20%) | Reports (10%) | Total (100%) |
|--------|------------------------|---------------------------------------|-----------------|-----------------|--------------|-------------|
| DJK3A  | 15                     | 15                                    | 13              | 15              | 9            | 67          |
| DJK3B  | 14                     | 15                                    | 12              | 15              | 9            | 65          |
| DJK3C  | 15                     | 16                                    | 13              | 16              | 9            | 69          |
| DJK3D  | 15                     | 16                                    | 14              | 16              | 8            | 69          |
| Average| 14.75                  | 15.5                                  | 13              | 15.5            | 8.75         | 67.5        |

Table 4. Respondents’ marks using newly developed electro pneumatic trainer

| Class   | Tubing connection (25%) | Solenoid valve connection skill (25%) | Discussion (20%) | Conclusion (20%) | Reports (10%) | Total (100%) | Improvement (%) |
|---------|------------------------|---------------------------------------|-----------------|-----------------|--------------|-------------|----------------|
| DJK3A   | 23                     | 22                                    | 18              | 18              | 9            | 90          | 23             |
| DJK3B   | 23                     | 23                                    | 18              | 17              | 9            | 90          | 25             |
| DJK3C   | 24                     | 23                                    | 19              | 18              | 9            | 93          | 24             |
| DJK3D   | 23                     | 22                                    | 18              | 19              | 9            | 91          | 22             |
| Average | 23.25                  | 22.5                                  | 18.25           | 18              | 9            | 91          | 23.5           |

In order to measure the academic performance (practical’s skills) in teaching and learning process, the four selected classes were asked to conduct the existing electro pneumatic practical by observing manually operating of electro pneumatic apparatus for Instrumentation (DEJ 3143) laboratory course. In measuring the students’ practical skills, the students were first assessed based on typical tubing and solenoid valve connection between individual electro pneumatic devices and relays, and manually tested the operation of the apparatus one by one. Once finished, they were required to submit a report.
based on manually tested practical. Next, the students were given the newly electro pneumatic trainer and were asked to carry out the connection of power supply, which was the connection of 240VAC from bench supply to electro pneumatic trainer, powered for air compressor, connection of solenoids valve toward all apparatus by using the banana plug cable on electro pneumatic trainers, and opened VB graphic on computer. Students had to observe and relate the VB graphical command with actual acting of the devices (i.e. operation of air motor, expand and retreat of solenoid cylinder, turning of 180°semi rotary motor and movement of linear drive) and once again they were required to submit a written report. On average, respondents scored 67.5% when using the manually connected electro pneumatic apparatus as compared to 91% when using the newly developed electro pneumatic trainer. This shows that there is an improvement in the overall students' performance at an average of 23.5% on their marks when using the electro pneumatic trainer. Table 3 also shows that the score on their practical skills, which was connecting the air tubing and solenoid valve, also increased at an average of 8.5% and 7.0%, respectively. Since items for reports, conclusion and discussion (refer Table 3 and Table 4) are not relevant for assessing their practicals skills, the findings will not be discussed in this paper. The practical skills were assessed based on standard rubric for Laboratory Practical Evaluation that has been standardized throughout the Electrical Engineering department.

6. Conclusion
The newly developed electro pneumatic trainer helps the students to achieve the objective and learning outcomes by enhancing the teaching and learning (cognitive), and psychomotor skill aspect through circuit installation, testing and troubleshooting. The development of electro pneumatic trainer also has been designed to expose the students by showing more apparatus related to electro pneumatic control in which five different output apparatus can be controlled using the VB platform. This is supported by questionnaires distributed to 175 respondents in which 97% of them agreed that the newly fabricated trainer is user friendly, safe and attractive. In addition, 96.8% respondents strongly agreed that there is improvement in knowledge development and hands-on skill in their learning process. Furthermore, through the Lab Practical Evaluation record, it is evident that the students improved their academic performance by an average of 23.5%. It also showed a high satisfaction among the respondents in perceptions and an increase of academic performance with regard to the usage of the newly fabricated electro pneumatic trainer.

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