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Enhancing the learning experience of undergraduate technology students with LabVIEW™ software

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ABSTRACT

Many universities and colleges, throughout the world, that deliver undergraduate programmes in science and engineering are currently incorporating virtual instruments as teaching, measurement and analysis tools for student learning. The aim of this study is to enhance the learning experience of undergraduate engineering students and stimulate their research interests by incorporating hands-on, hardware linked programming. The framework for the current research consisted of, initially, observing and recording the interest students showed in a graphical-based computer language for programming control and data acquisitions. Secondly, in the software laboratory sessions, the students were introduced to the concept of research activity and the use of computer software in such activity. LabVIEW™, an easy-to-use, interactive, graphical programming language that can be used to build virtual instruments was used in the current study. This software allows creation of sophisticated programs and applications in a shorter amount of time without needing an in-depth knowledge of computers or indeed programming languages. The methodology consisted of an introductory learning period for the LabVIEW™ programming language, followed by hands-on programming with a specific set of laboratory exercises aimed at solving typical industrial automation type problems. Finally the results of a detailed student questionnaire and created programs were analysed to establish the learning experiences. It was established that student experiences in designing and developing LabVIEW™ programs with associated hardware has hugely stimulated their interest and enthusiasm in the subject of industrial automation. Students acquired knowledge by direct experience, explored phenomena, visualized expected outcomes and experimented with possible solutions. Critically, the LabVIEW programming laboratory sessions undertaken during the course of this research has stimulate students interest in pursing further research at post-graduate level.

1. Introduction

The undergraduate engineering laboratory is often the most important opportunity for students to observe and explore real-world applications of fundamental theories learned in the classroom. However, the actual learning experience is often compromised by the lack of equipment. Furthermore, the rapid rate of change in the fields of technology poses challenging problems for academic institutions, specifically for the engineering disciplines (Ertugrul, 2000). The main problem is the provision of relevant and meaningful practical experience while laboratory resources such as hardware and infrastructure are often limited. Challenges also exist in exposing undergraduate students to high-level research activities so as to foster student interest in pursuing a research degree or indeed research career. In the current research, computer-based techniques are used to interface the students, whom are taking modules in industrial automation, with physical applications with suitable front-end design that is flexible and straightforward to implement. These computer-based techniques are presently being used by many academics and researchers at the author's institution as a research tool. The use of computer-based educational tools in laboratories has become more commonplace in many third level institutes that deliver programmes and courses in engineering and technology (Malki & Matarrita, 2003; Moriarty, Gallagher, Mellor, & Baines, 2003; O'Donnell, 1999; Schwartz & Dunkin, 2000; Trevelyan, 2004). Recent advances in technology and the falling cost of computing equipment have made it cost effective and

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feasible to implement advanced and interactive user-friendly systems without having to use very costly custom-written software and tools. Some researchers have extended the use of computer based tools in mathematics (Faraco & Gabriele, 2007). In their study, the researchers used LabVIEW to describe and simulate physical phenomena using a mathematical model. The varying strategies and cognitive styles used by the students were shown. The researchers established that the LabVIEW programs produced by the students encouraged the understanding of physical and/or biological phenomena. LabVIEW has also been successfully used for numerical Fourier transform (FT) calculations, which may also be used as an educational tool (Sevgi & Uluisik, 2006). These researchers reported a significant increase in the student understanding of the FT's when using the software. In a recent study (Kong, Yeung, & Wu, in press) the pedagogical value of remote-controlled experimentation revealed the potential to integrate the use of a LabVIEW system with the practice of scientific experiments. Various approaches have been taken, using LabVIEW, to impart the necessary competencies to engineering students to allow them implement real-time control solutions (Salzmann, Gillet, & Huguenin, 2000). These researchers achieved this goal by introducing the basic principles of control, and then by motivating the students to use PC's to the alternative traditional equipment. Graphical computing has been used successfully in the teaching of physics to undergraduate students by a number if researchers. Some researchers have successfully integrated the LabVIEW application in the learning strategies of a course in quantum physics for engineering (Orquin, Garcia-March, Fernandez De Cordoba, Urcheguia, & Monsoriu, 2007). Further research highlighted the advantages and disadvantages of teaching computer interfacing and instrument control techniques using both Matlab and LabVIEW to undergraduate physics students (Sharp, Glover, & Moseley, 2007). Orabi (2002) describes the implementation of LabVIEW, in a torsion experiment to allow the acquisition of real time data for display, analysis, control and storage. This researcher reported that the use of virtual instruments created with LabVIEW allowed quick investigation and data acquisition and also served to introduce many students to the use of virtual instruments. The time students took to complete the experiment was significantly reduced by using LabVIEW. In the field of electronics education, student understanding of the link between theory and application has always been a critical objective. LabVIEW virtual instrument software is a tool that can be used very effectively to promote student understanding of that link (Oldenburg, 2004). It can be employed to compare device theory with the actual operation of an electronic device, using an effective visual format. It can also facilitate the implementation of computer-aided circuit design and verification. The research reported that student evaluation of the LabVIEW programs was very positive with respect to their effectiveness in helping them to understand the link between theory and application. LabVIEW has been successfully applied to the implementation of distance learning (Zaimoviæ-Uzunoviæ, Lemeš, & Petkoviæ, 2001). Distance learning is an excellent tool to improve engineering education by providing flexibility to students and teachers. Development of distance learning courses is costly; therefore it is a must to decrease costs to provide flexibility in education. Virtual instruments are an excellent solution, as they significantly decrease costs for laboratory equipment. They provide access to expensive laboratories over the Internet or local area network (LAN)

As part of the current research, the links between research, student learning and graduate outcomes were also investigated. Issues concerning these links have been rising to the top of the agenda in recent years in higher education, whether in terms of national strategy, institutional policies, disciplinary practices or individual endeavor (Jenkins, Healey, & Zetter, 2007). Teaching and research are becoming even more intimately related nowadays as in a knowledge society all graduates have to be researchers. Furthermore, students must be educated to cope with the risks of uncertainties generated by the advance of science (Scott, 2002). The changing world, particularly in engineering, will demand unprecedented skills of flexibility analysis and enquiry. Teaching students to be enquiring or research-based is central to the range of skills required of the future graduate workforce. Research-led teaching refers to initiatives to bring the research and teaching functions of the university together. The aim is to enhance the students learning experiences by progressing the ways in which coursework teaching is informed by disciplinary-based research at all levels (Brew, 2006). However, some studies have concluded that the common belief that research and teaching are inextricably linked is an *"enduring myth"* (Feldman, 1987a; Hattie & Marsh, 1996; Terenzini & Pascarella, 1994). These studies, however, claim that high correlations do exist between research and the presentation aspects of teaching. It is claimed that good researchers are "*a little more likely*" to be better prepared as teachers and have better presentation competencies than non-researchers. Furthermore the study (Hattie & Marsh, 1996) claims that good researchers and good teachers are more enthusiastic, have greater breadth of coverage, are more committed to teaching, and appear more knowledgeable. Some research (Bourdieu, 1988) has indicated that students do not necessarily value research-active staff more than those that are not research-active. Undoubtedly, teaching and research can exist in a range of relationships with each other, and these relationships are shaped by the value-orientations of academic staff and the management of available resources (Coate, Barnett, & Williams, 2001). In a particular survey carried out in the early 1990s (Halsey, 1992), in a number of UK universities, it was observed that 90% of academics claimed that an active research interest is essential if an individual is to be a good university teacher Other research has indicated that if university teachers stop doing research then they will begin to repeat themselves and eventually loose touch with the student body (Jencks & Riesman, 1968). One particular study has shown that the existence of a nexus between the research and teaching roles was "mutually enriching" and that in practice the two often tend to merge and that the university environment is often conducive to achieving some "*sort of excellence*" in both areas (Neumann, 1992). Other investigations have postulated that research is necessary if instructors are to keep abreast of new developments in their field and to stimulate their thinking, and this in turn provides one basis for predicting a positive correlation between research activity and students' evaluations of teaching effectiveness (McCaughey, 1992).

The drivers of declining resources and the high value of research present challenges to academics who attempt to maintain a balance between teaching and research abilities. The long-standing central issue of the relationship between staff involvement in research in their discipline and their role as teachers of that discipline is presently a major concern for modern universities. There is a growing body of evidence to show that students may benefit from research activity, but for this to be maximized, the linkage has to be explicitly planned and constructed (Jenkins, Breen, Lindsay, & Brew, 2003).

It has been previously shown that the computer is a powerful instructional and motivational medium (Gibbons & Fairweather, 1998). Computer-based instruction (CBI) has been shown to be far superior to other instructional media in teaching of technological subjects due to a number of characteristics including; dynamic display, ability to accept student input and the ability to select between courses of action. Rigorous investigations of the impacts of educational technology on student learning require multiple studies and more than one methodological approach (Haertel & Means 2003). Furthermore, primary attention should be paid to how technology is used by students and teachers to affect the quality and degree of learning and what learning outcomes result from these uses (O'Neil & Perez 2003). It is the aim of the current author, in building up the research framework, to investigate whether the learning experience and outcomes of undergraduate students can be enhanced using the LabVIEW™ software. As a further aim, the laboratory instruction was used to determine if the learning experience can be used to stimulate an interest in research activity in science and engineering.

2. LabVIEW software

LabVIEW is a development environment based on a graphical programming language. This approach to developing applications significantly reduces the learning curve because graphical representations are a more natural design notation for engineers and scientists than text-based code. The tools and functions are accessed through interactive palettes, dialogs, menus, and hundreds of function blocks, known as VI's (virtual instruments). These VI's can be dropped onto a diagram to define the behaviour of the application being built. This point-and-click approach significantly reduces the time it takes to get from initial set up to a final solution. The LabVIEW graphical language is an intuitive way for scientists and engineers to develop their measurement and control applications. In addition to being easy to learn and use, the language also delivers the performance needed for advanced applications.

LabVIEW is best known as a data acquisition and instrument control tool. These capabilities are built into the language and are pervasive throughout the environment. The language itself naturally manages continuous, looping data acquisition operations, and delivers significant time savings to developers simply because the tool provides functionality throughout with an engineering and scientific perspective.

3. Laboratory hardware

In the current research a National Instruments DAQPad-6015 was used to interface the sensors and transducers available on a purpose-built input/output (I/O) board. The DAQPad is a multifunction data acquisition (DAQ) device which provides plug-and-play connectivity via USB for acquiring, generating, and logging data. The screw terminals on the DAQPad device provided direct connectivity so that sensors and signals could be easily connected. The device features 16 analog input lines with 16-bit accuracy when sampling at up to 200 kS/s, 2 analog output lines and 32 digital I/O lines. Each DAQPad was connected to a standard desktop while the instructor's desktop screen was projected onto a while board in the laboratory to assist the students in progressing through the laboratory sessions as shown in Fig. 1.

4. Current research

In the current research, the laboratory applications involve physical quantities such as voltage, rotational velocity, temperature and switching operations. A purpose-built electronic input/output (IO) board was set up incorporating temperature sensors, load cell, digital relay, DC motors with built-in encoder, light dependent resistors and buzzers. This board was interfaced to a USB data acquisition device in the computer running the LabVIEW software. Students were tasked to write programmes to acquire data from the board and control outputs to the buzzer, motor and Led's. Prior to undertaking these programming tasks, the students complete two, 2-h sessions in the laboratory to familiarize themselves with the LabVIEW programming environment. On completion of all the LabVIEW exercises, students completed a questionnaire to establish the effectiveness of the exercises in the context of learning.

4.1. Research framework and objectives

The framework for the current research is to initially observe and record the interest students showed in a graphical-based computer language for programming control and data acquisitions. From this step, through the use of various programming exercises, the effectiveness using the exercises as a learning tool was observed. Finally, the hands-on exercises were used to stimulate the student's interest in pursuing post-graduate studies by exposing them to a number of research projects that utilise the LabVIEW software. The primary objectives of the research were to:

Fig. 1. Undergraduate student LabVIEW™ Laboratory.

1. Effectively teach undergrad technology students LabVIEW with a focus on application.
2. Provide an effective learning environment for instrumentation and data acquisition techniques.
3. Stimulate student's interest in research through exposure to current research projects.

5. Study methodology

The students were introduced to the LabVIEW programming environment by guiding them through a set of custom-written notes to build a number of introductory LabVIEW programs. These programs introduced the students to the programming environment and building blocks of the G-code. These introductory programmes, which did not facilitate any I/O operations, were completed over a period of 4 h. Following the initial 2 laboratory sessions, the tutor demonstrated how to acquire an analog signal and display the signal magnitude on a VI. Subsequently the students used a thermocouple to generate a temperature signal and save the temperature data to an excel sheet. Finally, three 2-h sessions were run in the laboratory were the students communicated with the purpose-built I/O boards through a data acquisition panel using LabVIEW. Students from two undergraduate programmes were selected for the present study. These programmes were: (A) B.Sc. in Manufacturing Systems and (B) B.Sc. in Production Management. A total of 91 participants were involved in this study which was carried out over a period of 4 years.

5.1. Laboratory sessions

In the initial laboratory session where the students are introduced to the LabVIEW software, a number of worksheets were provided to them. By working through these sheets, the students get familiarised with the programming environment and data flow. The laboratory worksheets consist of step-by-step instructions for building the program. The first program that the students write is shown below in Fig. 2. It consists of a 60 s timer, which counts down from a time specified in the start control. The dial, which acts as an indicator, shows the remaining time as the program is run.

In Part 2 of the lesson, the students enhance the timer program by eliminating the "Start" control and using a single knob on the front panel, which serves two purposes. After the user sets the desired total time, the knob also indicates the remaining time. Thus the knob is acting both as a control (when the time is set) and as an indicator. In this example, the students learn how to achieve this double role in LabVIEW, using local variables. The students were encouraged to run the program with the "Execution Highlighting" Tool On, carefully observing how data flowed through the programme structure. In Part 3 of the lesson students learn how to create charts and graphs in LabVIEW. The difference between charts and graphs is discussed prior to the lesson. A program is created to display data from both a random number generator and virtual thermometer on a chart on the program front panel as shown in Fig. 3.

This program introduces the Bundle function which allows plotting of the data from two different sources. The students are encouraged to investigate the three modes of updating the data on the chart, i.e. strip chart, scope and sweep and to comment on each of the types in their report. Furthermore the students are requested to personalise the program by changing the appearance of the front panel.

In the second LabVIEW laboratory session, the students are introduced to the data acquisition hardware. In the first part of the lesson, each student writes a LabVIEW program to acquire a temperature reading from a K-Type Thermocouple connected to the DAQ panel. The VI allows the user to display the temperature in degrees Fahrenheit rather than degrees Celsius. A step-by-step guide allows the student to set up the channel on the data acquisition device. Each student is provided with a thermocouple and screwdriver to make the necessary connections to the screw terminal. The acquisition of the temperature data is tested in the NI-DAQ – DAQ Assist before returning to the LabVIEW program. The front panel and wiring diagrams for this program are presented in Fig. 4. In Parts 2 and 3 of the lesson, the students enhance the program by using a waveform chart to display data in real time and write the temperature data to a file. The students are then tasked with an exercise to include a warning light on the front panel where the temperature exceeds a certain value. By pinching the

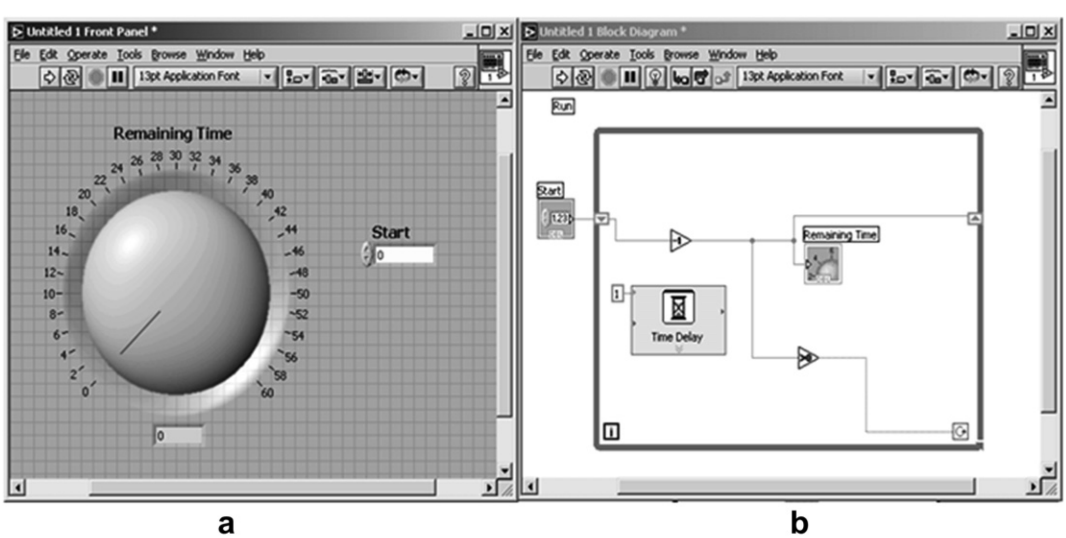

Fig. 2. First student LabVIEW timer program (a) front panel and (b) block diagram.

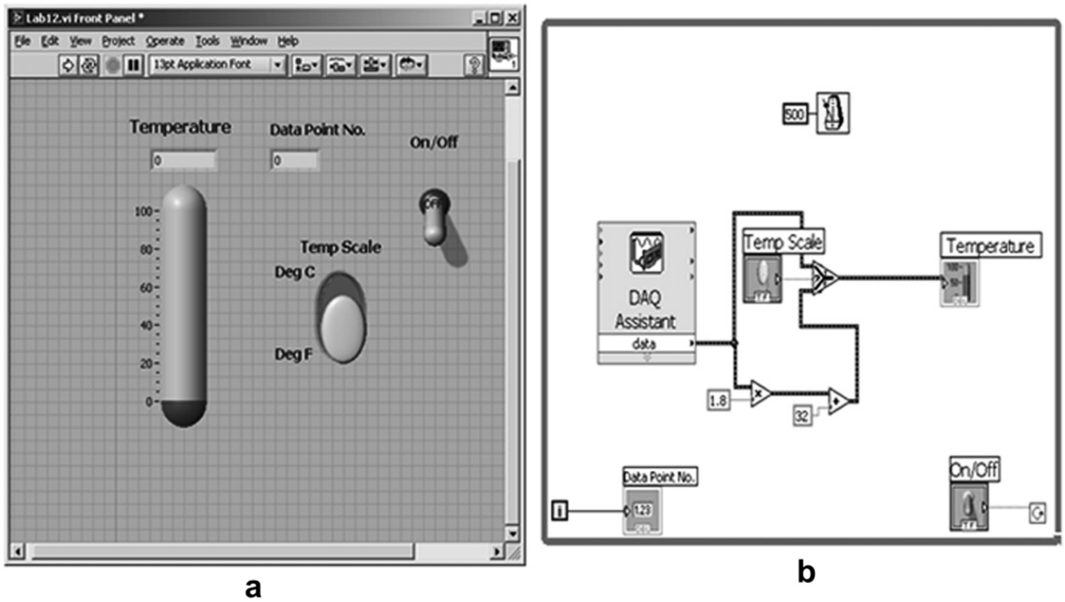

Fig. 3. Simultaneous charts program (a) front panel and (b) block diagram.

thermocouples between their fingers, the temperature increase is recorded on the front panel and stored in the excel file on termination of the program.

On completion of the second laboratory session, the operating principles of thermocouples are presented to the students by class handouts and a short presentation. Subsequently, the topics of signal conditioning and data acquisition rates are presented. This teaching method has shown, in this research, to enhance the student learning experience.

Following on from the initial 4-h period of LabVIEW programming, students were introduced to the purpose-built IO boards. The students were instructed on how to read and write digital signals. The students used this information to switch various combinations of eight LEDs at different intervals using time delays. Digital input signals were read from switches powered from the 5 V supply on the DAQ device.

The students were presented with numerous problems and control scenarios for which they had to write a LabVIEW program. An example of such a problem is:

- *Read and log a signal from the temperature sensor at a frequency of 4 Hz.*
- *When the temperature reaches a temperature of 25°C, switch on LEDs 1 and 3.*
- *When temperature reaches 25°C switch on Motor No.1 (with fan).*
- *Switch on the buzzer after the motor has run continuously for 20 s.*

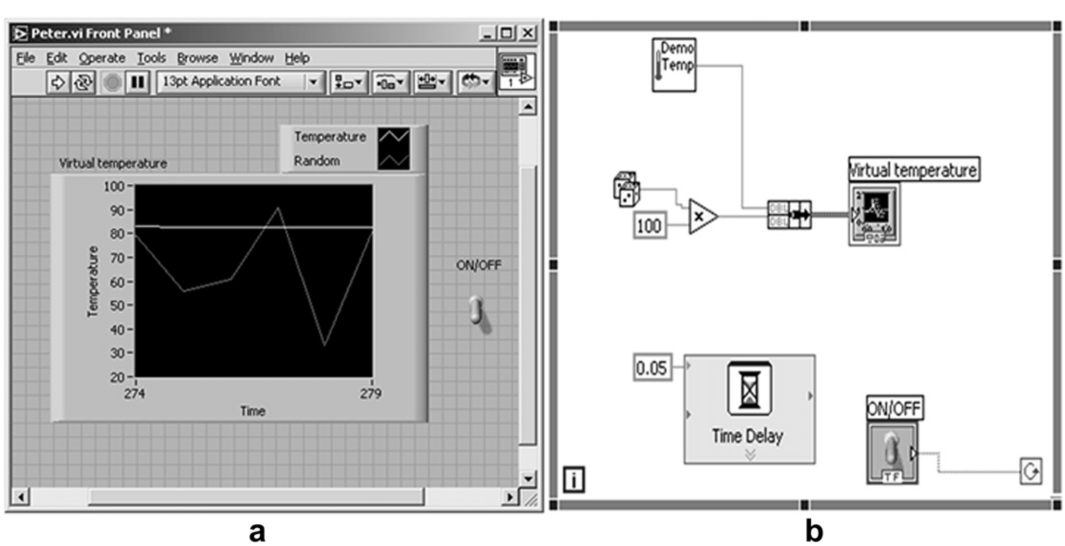

Fig. 4. Thermocouple application LabVIEW program; (a) front panel and (b) block diagram.

Finally the students are presented with the LabVIEW front panel in Fig. 5 which is not accompanied by any code. They are tasked with writing a program to allow a user to interface with the purpose-built control boards utilising all the controls and indicators on the front panel shown in Fig. 5.

6. Data collection and analysis

In the author's experience, the use of a graphical programming language such as LabVIEW to allow technology students use a PC to interact with sensors and transducers promotes both curricular and cognitive skills. The final programs produced by the students were analysed individually to determine if the following learning outcomes were achieved:

1. Student understanding of data flow and programming structures such as loops, case structures, and sequence blocks.
2. The strategy used in planning and developing the programs.
3. The programming strategy used for communication with the I/O boards.
4. The ability of the student to test their program, eliminate bugs and build in fail-safe structures and error handling in the code.

6.1. *Analysis of learning outcomes*

The above learning outcomes were analysed by direct comparison of the student's code with that written by a certified LabVIEW programmer. In terms of data flow, an efficiently written program will run in minimum time with minimum processing time used in the code execution. An internal PC clock function was used to compare the code execution times of the programs written by the students to that of the programmer. Using this technique, and with the LabVIEW data flow indicator active, it was possible to gauge the efficiency of the student's code. In terms of the strategy used in planning and developing the programs, the use of VI's and Sub VI's in the overall program increased program efficiency. An efficient program will call sub VI's within the main program when required. Each student's program was assessed for the correct placement of these SubVI's. The correct programming strategy used to communicate with the I/O boards varied with the signal type. The standard method of communication is to use the preloaded wizard to establish the connection. A less efficient method utilises blocks of code that are edited to communicate with the hardware. Therefore the learning outcome on programming strategy used for communication with the I/O board can be analysed by assessing the method used by individual students to make the communication. The

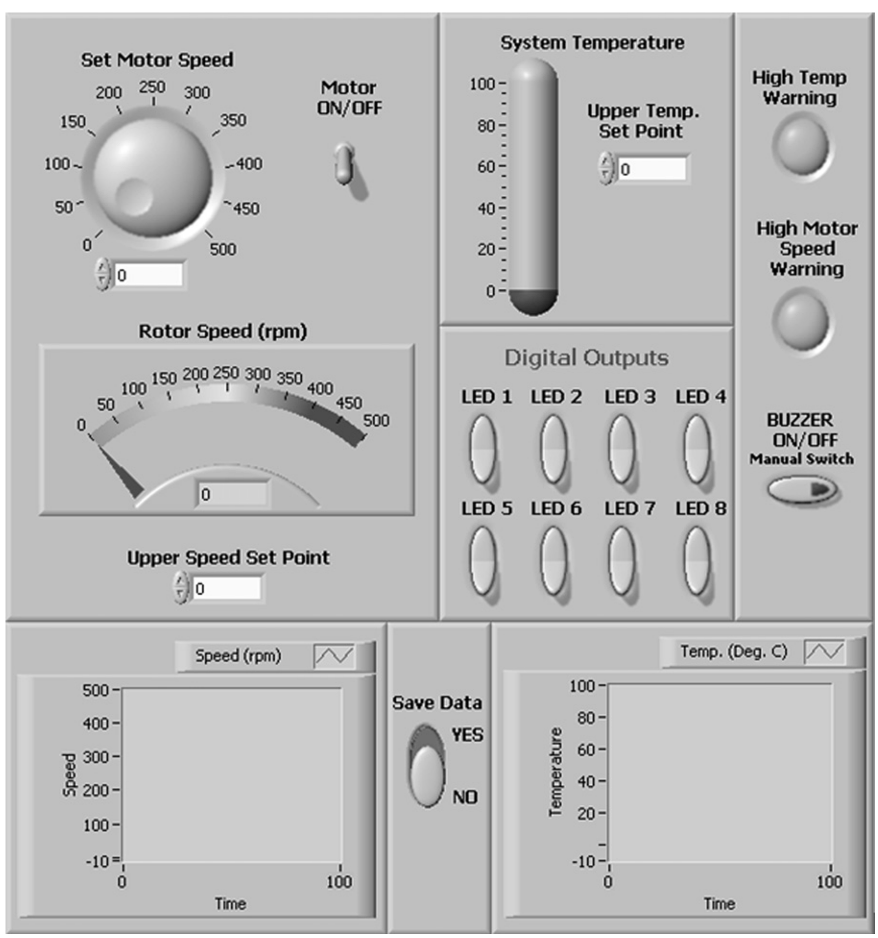

Fig. 5. LabVIEW interface for final programming exercise.

ability of the student to test their program, eliminate bugs and build in error handling in the code was analysed by using an assessment method established by the author. This method involves testing the program with a series of random inputs and recording the program behaviour. Furthermore, qualitative assessment was used to determine if the student understood the basis of the fail-safe structures and code error handling. The student cohort was questioned to determine whether the LabVIEW laboratory sessions promoted an interest in further investigation and use of the software. Following a presentation to the students on research activity within the Faculty of Science and Engineering incorporating LabVIEW, the student's interest in pursuing post-graduate research was gauged.

7. Results and discussion

The data collected was obtained from both student feedback and from an analysis of the LabVIEW programs written by the students. Initially, the students understanding of the software was determined by assessing the students use of programming structures and general methods in communicating with the I/O boards. 91% of the students successfully used a while loop while 70% of the students ran timed sequence structures. Only 19% of the student cohort used Sub VI code blocks in the implementation of their programs as shown in Fig. 6.

In terms of functionality, the programs were assessed on their ability to communicate with the purpose-built I/O boards. The result of this assessment is presented in Fig. 7. It was observed that 86, i.e. 94% of the students successfully wrote digital signals with LabVIEW to switch the LEDS and buzzer. However, only 12 of the students were successful in the acquisition of the motor speed signal. This highlights a necessity to provide increased laboratory time on the subject of acquiring signals from digital encoders. The main problem encountered by the students with this aspect of the exercise was hardwiring the encoder to the data acquisition device.

From the data presented in Fig. 6, it is evident that the LabVIEW software was effectively taught. As described in the research framework, the teaching focus was on application of the software. This aspect of the teaching has been successful in allowing the students to gain a solid understanding of the software. Traditionally, at the author's institution, the teaching of data acquisition techniques had been confined to signals simulated by the computer. The absence of real-world signals disadvantaged the students in terms of software application in the teaching laboratory. However, with the approach described in the current research, an effective learning environment has been provided for instrumentation and data analysis techniques, i.e. one of the primary objectives of the research. As demonstrated by previous researchers (Oldenburg, 2004), the LabVIEW software was established as a tool, in the current research, to be effective *n* promoting student understanding of the link between theory and application.

Undoubtedly, the student's interest in research activity has been increased through the exposure to the LabVIEW software. It was established in the current research that teaching and research activities can exist in a healthy relationships with each other, and these relationships are shaped by the value-orientations of academic staff and the management of available resources (Coate et al. 2001).

Student interest in pursuing further study in the area of applied research is presented in Fig. 8. The students were also asked whether they would use LabVIEW in further coursework assignments during their final year of undergraduate study.

Each student was interviewed within one week of completing the laboratory programming exercises to determine their attitudes to using computer-based tools as a teaching resource. Through a questionnaire, the students rated their success at achieving the learning outcomes presented in Section 6. This *perceived* success was compared to the *actual* success in achieving the learning outcomes. The results of this comparison are presented below in Fig. 9. Interestingly, the success perceived by the students in achieving the learning outcomes closely correlated with the actual success as shown in Fig. 9. This demonstrates that the students are confident in their ability to use the software and more importantly that this confidence is justified.

Furthermore, from discussions with teaching assistants involved with this research work, it is obvious that by utilising computer-based educational tools in the laboratory, students have demonstrated an interest and excitement in learning. High engagement levels were reported at all the laboratory sessions. Furthermore, informal feedback by some students has indicated clearly that they have a keen interest to participate in further laboratory sessions similar to that described in the current research.

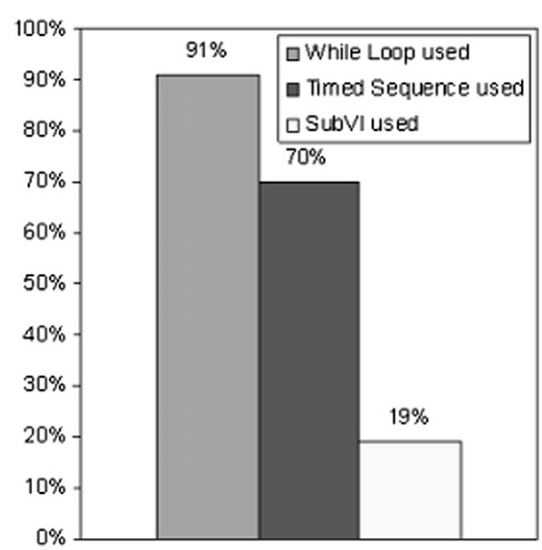

Fig. 6. Results of software understanding assessment.

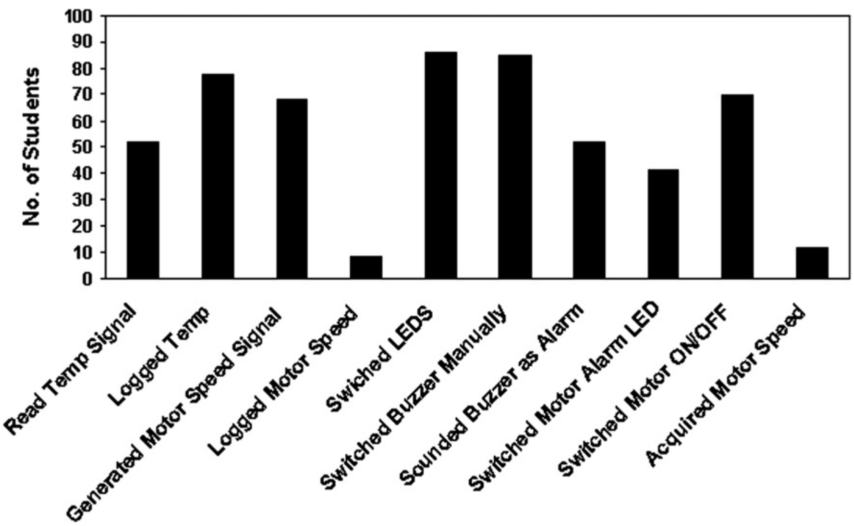

Fig. 7. Results of I/O activities for purpose-built board.

The integration of research into the undergraduate curricula is seen as a natural way of operating. One of the ways this has been achieved by the current author is by means of embedding research and research techniques into curricula. This has been successfully achieved by incorporating LabVIEW into automation modules to enhance both the teaching and learning experience. By using the software, students reported an enhanced learning experience in automation, control and instrumentation principles. Furthermore, the final year technology student groups involved were exposed to high-level research projects carried out by academics, in which LabVIEW™ has been used. Evidence has shown that the exposure to research has encouraged and motivated the students to further explore the subject of automation and automated systems in the context of masters and doctoral studies. In the current study, the majority of students (94%) acknowledged that LabVIEW was enjoyable to learn and use. 70% of the students reported that they would further use the program in other assignments during their final year. This programming language would replace traditional text-based languages which will result in shorter project completion times. Interestingly, 45% of the students claimed that that they would consider further study having observed a number of master and doctoral research project which utilize LabVIEW. This highlights the benefit for both teaching and research if an academic department or faculty can develop a strong research component while maintaining excellent teaching at undergraduate level. In order to support this mission, undergraduate students must become an integral part of the research programmes. This means that we can not just bring research into the lecture room as a seminar series, but the undergraduate students must be involved in gathering data, building experimental rigs, running simulations and undertaking literature reviews.

In the current study, it was highlighted that the provision of relevant and meaningful practical experience can stimulate student's interest in the subject areas in which they study. The computer-based technique used to interface with physical applications with suitable front-end design that is flexible and straightforward to implement was well received by the students. The low cost approach to teaching computer-based control and measurement can be easily adopted in any third level automation laboratory. Furthermore, the system is highly flexible which makes it suitable for teaching at all levels of science, technology and engineering programmes at college and university.

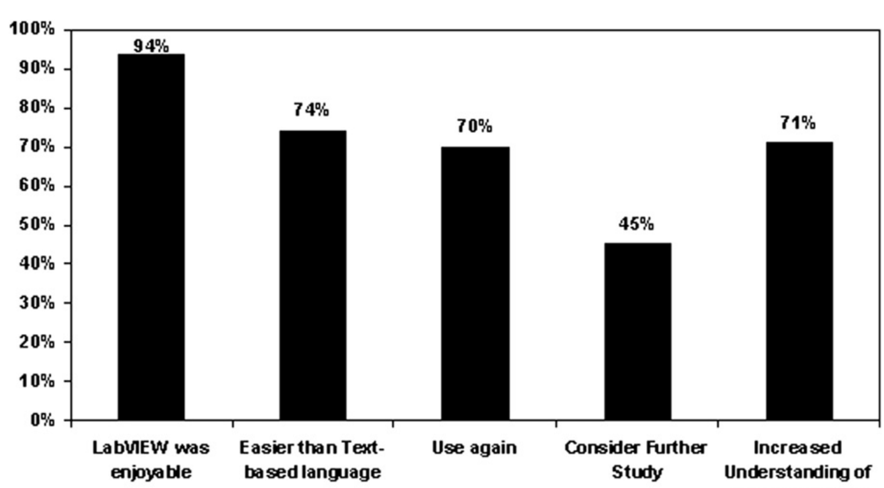

Fig. 8. Results of student survey.

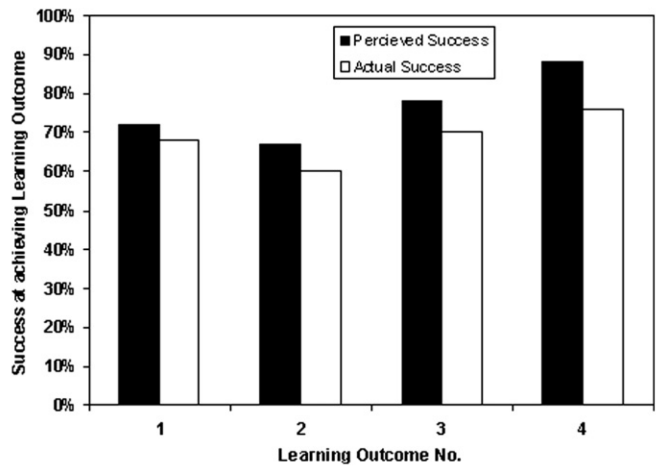

Fig. 9. Comparison of perceived and actual success at achieving learning outcomes

8. Conclusions

Today, engineering and technology education possesses many challenges. In the area of automation and control, low cost computer-based simulation and automated control equipment are paramount to effective teaching of this subject. Experimentation and hands-on training are the key issues in engineering education. Introducing and integrating automation into an undergraduate laboratory improved student productivity. The interaction between instructor and student focused both on programming, experimental set up and discussion of the key concepts covered in the practical exercises. The introduction of laboratory automation has become a powerful tool in emphasizing the understanding and exploration of the fundamental physical principles presented in automation and control teaching laboratories. The author has found that design and development of LabVIEW programs have encouraged and stimulated student's interest and enthusiasm in the automation topics delivered in lecture sessions. Furthermore the students have demonstrated a better understanding of the principles of automation and control. Students acquired knowledge by direct experience, explored phenomena, visualized expected outcomes and experimented with possible solutions. This highlights the importance of extending the use of computers to simulation, data acquisition and control for student learning. LabVIEW has presented the students with an opportunity to model, manage and represent signals in a user friendly and manageable way. Critically, the LabVIEW programming laboratory sessions undertaken during the course of this research has stimulated student interest in pursing further research at post-graduate level.

Data gathered for the current research within the past year has shown that 18.4% of the students who participated in the research project have enrolled on both taught and research post-graduate programmes. Typically, the uptake of research for such a population at the author's institution is approximately 9%. In the recent survey, 84.2% participants claimed that the hands-on instructional teaching with LabVIEW motivated them to pursue the post-graduate qualification. In countries that aspire to have a knowledge-based economy, higher degrees are seen as a necessity for many of third level graduates. Therefore it can be concluded the current research exercise is invaluable in meeting this goal.

To further develop this study, the author is currently planning to introduce LabVIEW programming to all undergraduate courses in the engineering department at the author's institution. Furthermore by incorporating new teaching staff in the delivery of the academic modules, it is planned to determine whether a teaching-research nexus can be fostered by the individual staff.

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