INDUSTRIAL AUTOMATION: PROVIDING STUDENTS WITH RELEVANT PROBLEM SOLVING AND ANALYTICAL SKILLS

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ABSTRACT

Groover defines automation as the technology by which a process or procedure is accomplished without human assistance [1]. Automation permeates through all levels of modern manufacturing, from automated vision systems which are employed to check quality, to PLC controlled assembly lines, to pneumatically controlled actuators to hold a workpiece during production, and more. Because of this level of infusion it is paramount that the engineering graduate has the skills required by industry to design, develop and evaluate solutions to industrial automation issues.

Strobel & Barneveld indicate that “Problem Based Learning (PBL) is significantly more effective than traditional instruction to train competent and skilled practitioners and to promote long-term retention of knowledge and skills” [2]. With this in mind how automation material is delivered on an undergraduate programme, has been redesigned using the CDIO philosophy. Traditionally material was delivered using a mix of lecture and instructive practical sessions, while assessment consisted of continual assessment and end of term written examination.

This approach has been changed to reflect a new CDIO PBL approach, students are required to conceive, evaluate, optimise, implement and operate the solution to the prescribed problem. While this move to the CDIO approach is in its infancy this paper outlines the automation concepts in which the students are required to show competency, it documents both qualitative and quantitative feedback from the students involved and outlines a comparison between the previous and new approach in terms of student performance, the comparison indicates an 18.5% improvement in academic performance post switch.

This paper outlines and illustrates how the switch to a CDIO approach with a specific focus on industrial technology e.g. LabVIEW, motors, PLCs etc. encourages student engagement but more importantly helps promote graduate attributes and skills desired and required in their role as engineers in an industrial environment.

KEYWORDS

Automation, graduate attributes, problem solving.

1. Introduction:

Universities seek to produce graduates who are knowledgeable, articulate, collaborative, responsible, creative and proactive. Indeed employers seek out these attributes in their prospective employees, "employers expect graduates to have generic qualities and attributes beyond an ability to recall current theories and facts" [3]. However it can be difficult to marry the academic requirements of particular programmes with these desirable graduate attributes.

It is the role of the University and/or lecturer to ensure that the student has the required level of academic knowledge, which is easily quantifiable in terms of traditional assessment techniques. However skills such as collaboration, creativeness, responsibility etc. are less tangible and are therefore more difficult to both assess and incorporate into the traditional lecture based approach. The question arises therefore how best to ensure that graduates have both the technical knowledge and softer skills required to result in a more rounded and desirable graduate.

Examining the technical requirement initially, research has shown that, "regardless of the subject matter, students working in small groups tend to learn more of what is taught and retain it longer than when the same content is presented in other instructional formats" [4]. The modern industrial environment is based on teams of people working together to manufacture a product, e.g. quality control who integrate with production, who liaise with purchasing and so on. Therefore while group work promotes enhanced academic performance, the ability to work successfully in a group is fundamental to operating successfully in an industrial environment. Thereby helping to promote and engrain the desirable graduate attributes into the student.

Another graduate attribute required by an engineering graduate in industry is the ability to approach problems from a unique perspective and to offer creative solutions. These skills of creativity and responsibility can be imparted to the students via Problem Based Learning (PBL). PBL is "significantly more effective than traditional instruction, to train competent and skilled practitioners, and to promote long-term retention of knowledge and skills" [2]. This form of active learning defined by Prince as "any instructional method that engages students in the thought process" [5] has the added bonus of increasing the knowledge retained by students but also works towards simulating a more realistic workplace environment, thereby preparing the students for life in the workplace.

From Bloom's Taxonomy [6] in the cognitive domain it is evident that the foundation to students successfully remembering concepts & theories is to enable students to "evaluate, analyse and create" solutions to problems. CDIO – conceive, design, implement and operate, links hand in hand with the problem based learning approach. Students are required to examine problems as part of a group and together design solutions to the issue. Having outlined the required graduate attributes, this paper aims to compare and contrast the performance of students on an industrial automation module after the switch to a CDIO/PBL approach. The paper will examine the students' academic performance and will also indicate how other graduate attributes can be enhanced through projects such as these.
The paper focuses on the delivery of a particular module and will initially examine the traditional, lecture/lab/exam format approach previously used to deliver the material.

2. Traditional Approach:

This module selected for examination, Automation 1, is an introductory automation module, lectured to 3rd year engineering students prior to the students 8 month industrial work placement.

The objectives of this module include:

- To introduce the student to motion systems and sensors applications in automation.
- To introduce the student to basic process control
- To introduce the student to indexing and feeding systems as used in manufacturing.
- To introduce the student to Programmable logic controller hardware and software.

Because of the location of the module, in the degree structure a fundamental objective of the module is to prepare the students for work in an industrial setting. It is therefore important to make the students aware of the various technologies they will encounter and typical problems they may be asked to solve or help solve.
Traditionally this level of awareness was examined using 2 mid-term exams, where students were given 30 minutes to develop a solution to both a PLC and pneumatic question.
The exams would be corrected and feedback returned to the students.

2.1 Typical PLC Question:

- Switch X1 is switched on and off twice after which light Y2 goes on.
- As long as X2 is on Y3 will then go on for 2 seconds before the system resets.
- If X3 is pressed at any time the system resets.

Students were asked to develop their solution to the problem and to input the code into the PLC unit. The objective of the midterm was to determine the student's level of knowledge of the PLC unit and their ability to extract the correct code from a prescribed problem.

2.2 Typical Pneumatic Question:

- A package is passed from Position A to Position B using two double acting cylinders.
- Cylinder 1 will extend slowly under control when the system knows that Cylinder 2 is in its home (retracted) position and a start button is pressed.
- When Cylinder 1 reaches the end of its stroke, there is a delay –after which Cylinder 2 extends automatically.
- When Cylinder 2 has extended fully – Cylinder 1 returns to its original position, Cylinder 1 reaching its home position allows Cylinder 2 to return to its starting position.
- The only manual intervention into the system is the start button all other operations are controlled automatically, using limit switches.

The students were asked to draw, label and number the pneumatic circuit, thereby establishing their level of academic knowledge of the system.

However while both of these mid-term exams evaluates the students' academic understanding of the system, they do not investigate their ability to creatively solve a problem; they do not require an answer to be articulated or help to develop collaborative skills.
Therefore there is potential to improve how these skills are integrated into the module and to determine if by integrating these skills if the students' academic performance increased. Section 3 examines the move towards a CDIO approach in material delivery.

3. Moving towards a CDIO Material Delivery Approach

Before deciding on the alternative approach it was necessary to consider what outcomes were desirable, these included increased engagement with the subject matter, increased knowledge of the subject matter, problem solving skills, creative solutions, collaborative skills, increased student responsibility/ownership and the ability to articulate their findings.

To achieve this balance in outcomes it was felt that the best approach was to offer the students a choice of a number of projects, each of which would be in the format of a one line problem statement. This type of problem statement is similar to those used in 6 sigma projects where engineers condense the problem to a specific statement to be reviewed. It was hoped that by prescribing the projects in this manner that the students would have more scope for creativity in their design of solution, use of material, size, shape, etc.

Academic theory, worked examples, practical examples were delivered as normal in the lecture environment; students were instructed using practical laboratory session on pneumatics, PLCs and LabVIEW, similar to the approach for previous years. However 4 weeks of Lab time, (2 hrs. per week, 8 hours total) at the end of the semester were ring-fenced for project work.

As mentioned in Section 1, combining students into groups has the benefit of increased subject matter retention but also helps prepare the student the collaborative atmosphere in industry. In total there were 13 students taking the module, the students were divided into groups 3 groups of 3 and 2 groups of 2, 5 groups in total.

3.1 Project Outlines:

The projects were devised to be relatively simple, but with scope for student creativity. The students were given the list of projects in the 2nd week of term, and asked to have designs considered by Wk 4, if material/equipment needed to be purchased this information was needed by Wk 6, to facilitate a project start in Wk 8 of term. All students were made aware of this timeline; however as will be seen by some of the feedback comments in Section 5, the importance of frontloading the work was lost on some of the groups.

<u>Project 1:</u>
To design and develop a conveyor belt system capable of delivering a part 40mm by 40mm by 40mm from a predefined start position to a predefined stop position.
The system starts when a start button is pressed; there is also an E-stop in the system.

<u>Project 2</u>
Using LabVIEW you are required to develop a system capable of recording the impact force on a metal plate. The system is to be portable, the maximum force is to be recorded and displayed on the screen at all times, while each individual score is also presented.

<u>Project 3:</u>
You are required to develop an automatic washing line, the system is to have the capability to detect rain, when rain is detected, the washing line retracts, when rain has subsided, the line assumes its original position.

Project 4
Using pneumatic cylinders you are required to design and develop a system of transporting a golf ball from a starting position to the hole. System should be enclosed to ensure the ball is not tampered with, when the ball enters the hole it should return to the start position.
Each cylinder should be controlled with a different button and not necessarily in an order 1,2,3,4.

Project 5
Using a DC motor as a generator, develop a wind turbine capable of recharging a battery.
You are required to conceive the design of the turbine through researching turbine blades etc. and then develop a system of harnessing the energy created.

4. Results:

4.1 Completed Projects

All five groups completed the projects within the prescribed timeframe; the average percentage awarded for the projects was 24% from a possible 30%, with the highest group achieving 28% and the lowest group achieving 19%.
Students were encouraged to conceive and develop their own solutions to the prescribed problems, for example Figure 1 illustrates the impact testing assembly. Here a metal plate is attached to a load cell, which in turn is interfaced with LabVIEW, when a force hits the plate; this is displayed on a graphical user interface, Figure 2.

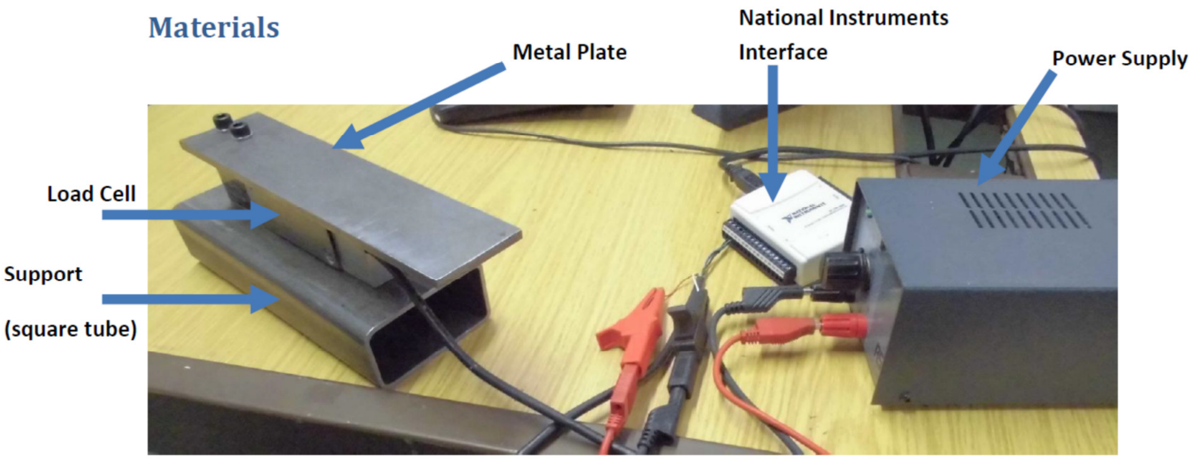

Figure 1 Project 2 - Impact Testing

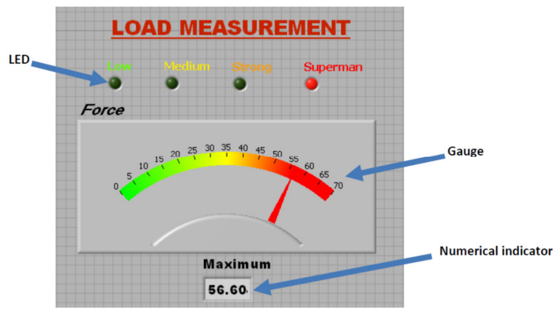

Figure 2 Project 2 - Graphical User Interface

Similar prototypes for the remaining four projects were developed by the students, and while in some instances the design and prototypes are rustic, all prototypes were functional (Figures 3 - 6).

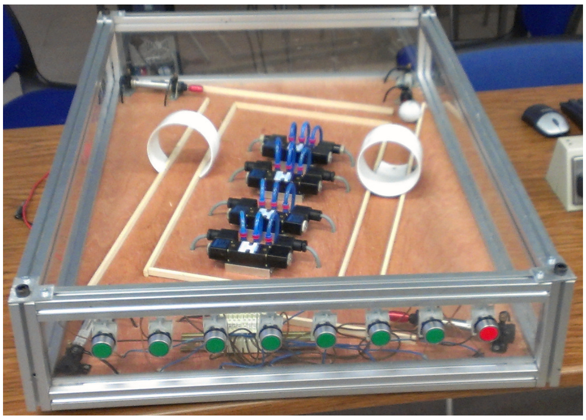

Figure 3: Completed Project 4

Figure 4: Completed Project 5

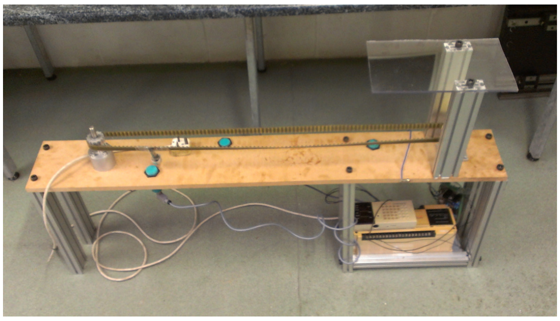

Figure 5: Completed Project 3

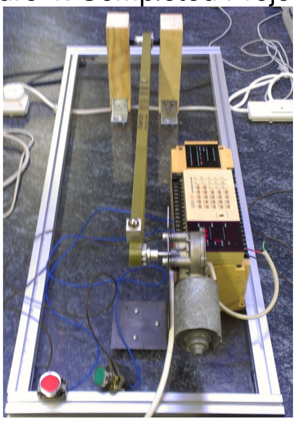

Figure 6: Completed Project 1

However the development of working prototypes is only one aspect of the investigation, it is now necessary to examine the overall module results and to compare these to the results of previous years, to establish if this change in philosophy was reflected in the grades awarded to students.

4.2 Inter year Grade Comparison

Before comparing Class A (2011/12) to Class B (2012/13), it is first necessary to establish the base level of ability between both classes. The industrial automation module is a Year 3 module, therefore to facilitate a comparison between groups of students the grade point average or QCA of both classes to the end of Year 2 was calculated.
Class A had an average QCA of 2.517, while Class B had an average QCA of 2.514, this represents a difference in abilities of 0.11%. In other words, the ability of both classes was almost identical at the end of Year 2, before entering the module under consideration.
It is therefore possible to compare the performance of the students across both years to determine the effect of moving to a CDIO approach.
Student's performance in end of semester, module final exams, for each year was captured and Figure 7, illustrates the difference in performance, between Class A and Class B.

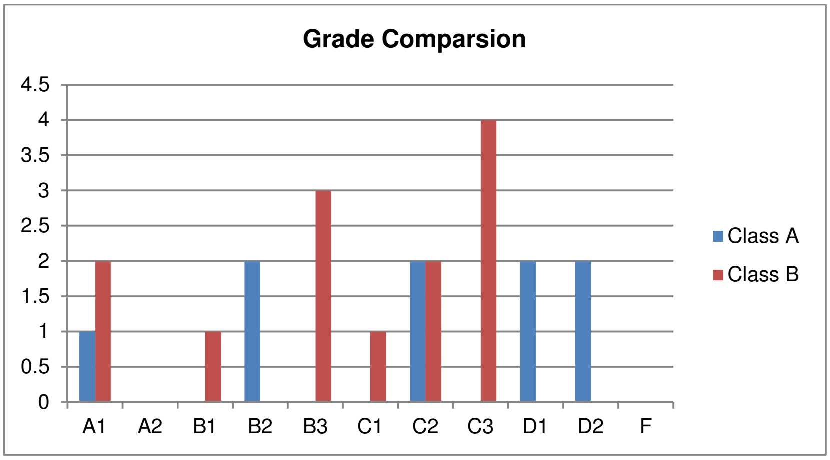

Figure 7: Grade Comparison

As can be seen from Figure 7, Class B performed significantly better than Class A, reflected in an 18.5% improvement in the module QCA from Class A to Class B. The module QCA increased from 2.27 in 2011/12 to 2.76 in 2012/13. As stated earlier the difference in ability levels between both classes at the end of Year 2 was 0.11%, therefore an 18.5% improvement in student performance is quite significant. It is obviously natural to expect some variation between class performance in end of year exams year on year, however an 18.5% improvement represents a significant level of academic improvement.

While academic improvement is welcome, as mentioned in Section 1, the objective of this study was to help prepare the students for an industrial placement. To this end after project submission the students were asked to fill out a feedback questionnaire, Table 1.

Table 1: Feedback Questionnaire

Question No.	Question	Scale	Average response
1	Compared to traditional mid-term tests you are familiar with from other modules on your programme. How did you find this practical project?	1 no benefit – 5 very beneficial	4.6
2	Was the project enjoyable?	1 not at all, 5 very enjoyable	4.1
3	Before the project, were you confident you understood the various automation examples as demonstrated in Lectures and Labs?	1 not confident, 5 very confident.	2.9
4	Did the project reinforce that perception or did it highlight areas were you needed to work on?	1 no difference 5 showed up weaknesses	4.2
5	Would you say you have a greater understanding of the practical applications of various automation systems after the project?	1 not at all, 5 significant more knowledge	4.5
6	Were the projects challenging?	1 too easy 5 too difficult	3.9
7	How do you feel you addressed the design phase of the project?	1 Poorly planned - 5 excellently planned	3.8
8	Project timeframe	1 too short, 5 too much time	2.9
9	This project has provided problem solving skills suitable for an industrial environment? (time management, design considerations, prototype development)	1 not at all - 5 relevant skills	4.3
10	Relevant lab equipment was easy to access and readily available	1 not at all – 5 very	3.9
11	Level of academic/technical support, assistance	1 not helpful – 5 very helpful	3.9
12	The project improved my understanding of design considerations in industrial automation?	1 not at all – 5 very much	4.3

5. Discussion:

Table 1 illustrates the data obtained from the feedback questionnaire, here it is apparent that the students enjoyed the practical aspect of the projects and when compared to the traditional mid-term tests, found the practical projects more beneficial.

Independent research or independent project work, mimics real life industrial problems in that students need to find solutions to problems which arise during the development of the prototype. While attending lectures is beneficial, it is only when faced with a technical issue that a true understanding of the material is experienced. This is evidenced in the answers to Question 4 & 5, where students felt that the project highlighted weaknesses in their ability but that having completed the project they students had gain significant more knowledge in the subject area.

A key objective of the project work was to expose the students to tight deadlines, associated with modern manufacturing; it hoped to promote the ethos of front loading the design phase to facilitate ease of manufacture and prototype development. On average, in answer to Question 9, the students felt that the project helped promote key skills such as time management, collaboration and creativity.

When asked "What advice would you give yourself now if you were to start again" the constant theme in feedback was in relation to time management;

- "Plan better, use time more wisely"
- "Plan ahead and give more time thinking than actually doing"
- "Plan carefully, prepare working drawings and develop code as early as possible"
- "Before writing the programme, in labview, think on paper about the signal conditions, outputs."
- "Manage time better, don't spend too much time on one part"
- "Allow more time for practicing automation on the project than worrying too much about the aesthetics"

In relation to providing students with key graduate attributes, promoting the awareness of time/project management through project work, represents a significant step forward in the preparation of students for work in an industrial environment.

When asked what aspects they particularly enjoyed, the theme in feedback was in relation to a sense of accomplishment:

- "Using equipment and thinking outside the box"
- "A sense of achievement when I saw the project assembled and working"
- I found this much more productive that having 12 weeks of studying theory"
- "Seeing the code successfully working"
- "Building the actual project"
- "Enjoyed the development"

By providing the students with a prescribed problem, but by not limiting the potential solutions it is apparent that the students enjoyed thinking creatively about the prescribed problem and taking the solution from the idea generation phase right through to the working prototype.

The final question asked was if the students thought the project better prepared them for an industrial placement and why. The answer was uniformly yes, for a variety of reasons:

- "Problems encountered during the project has increased my problem solving skills"
- "Because we just knew what the outcome had to be and we had to find a solution to the problem"
- "Work in autonomy"
- "Yes because if gave me knowledge that I didn't already have."
- "Planning, time schedule, know how operations work, were all incorporated."

These answers, from the students, help to justify the move towards a CDIO approach, the students awareness of items not directly or implicated stated in the project outline e.g. planning, problem solving skills, autonomous learning etc., were reinforced.
However not all students felt better prepared for industrial placement "No – 12 weeks was too short a time period to feel comfortable", which illustrates the need to a CDIO approach across various modules and not in isolation for one module in a four year programme.

6. Conclusion:

The objective of this study was to determine if a move towards a CDIO approach would impart relevant problem solving and analytical skills to 3rd level students. Having compared class results pre and post the switch is was apparent that students' academic performance increased with the move to the CDIO approach. An 18.5% improvement in class QCA from Class A to Class B was recorded.
However equally importantly, desired graduate attributes such as creativity, collaboration, responsibility and being proactive, which under a traditional approach would not be encouraged, were strengthened through the use of the CDIO approach.
It can be stated therefore that students who experience the CDIO process acquire knowledge over and above academic knowledge, which helps prepare those students for life in an industrial environment.

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BIOGRAPHICAL INFORMATION

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