

# **AC 2007-1327: DEVELOPMENT OF SCADA EXPERIMENTAL SYSTEMS THROUGH STUDENT PROJECTS TO ENHANCE THE AUTOMATION CURRICULUM IN A MANUFACTURING ENGINEERING TECHNOLOGY PROGRAM**

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# **Development of SCADA Experimental Systems through Student Projects to Enhance the Automation Curriculum in a Manufacturing Engineering Technology Program.**

## Abstract

The use of Supervisory Control and Data Acquisition (SCADA) systems in industry is on the rapid increase, especially with developments of modular instruments and sensors that are easily controlled through Ethernet or other industry network standards. The need for skilled personnel to implement and utilize these systems is also increasing. Courses which incorporate SCADA applications are offered widely across the nation and in many colleges. These courses often include theory and laboratory component in which students learn how to implement and program these systems. By providing an experiential education in manufacturing systems automation in an engineering technology curriculum, students are better prepared upon entering the workforce. However, most SCADA experimental hardware and software are often very expensive and many colleges cannot afford them. This paper presents the development of a hybrid low cost experimental system. It is based on National Instruments low end data acquisition card with LabView™ as the software interface. The rest of the system is built from a collection of inexpensive sensors and output devices to simulate a temperature control system. The hardware is designed and built by the students. Also presented in this paper are the details of the hardware; and the results of a survey that was carried out to determine how well this approach satisfied the academic goals and what challenges the students faced as they worked on these projects. This approach enables academic programs with limited funding to provide important hands-on experience in automation to students, thus enabling them to enter the workforce better prepared. The paper also demonstrates the effective utilization of limited resources to provide more access to practical academic programs.

## Introduction

As the trends in manufacturing automation continue to evolve, process control is becoming more and more data intensive. This implies the need for more supervisory control and data acquisition (SCADA) systems. Surveys of the future of SCADA systems<sup>1,2</sup> show trends towards supervisory control, distributed control systems, use of programmable controllers (PLCs), smart sensors, and use of networking systems such as Ethernet or DeviceNet. SCADA systems are currently used in a wide variety of applications ranging from process control to energy distribution and management, and to telemetry and agricultural systems, just to name a few. Because of the continuing increase in the use of SCADA systems, Engineering and Technology educators need to periodically reexamine the skills required by our graduates to meet the multi-faceted challenges in their future workplaces. The need for continuous reengineering of the curriculum is driven by the global desire to reduce costs and increase productivity in a competitive economy. It is therefore imperative that the subjects taught should correspond to those skills needed in this

competitive industry. This will expose students to the leading advances in technology, and familiarize them with the latest trends in process control and data acquisition.

As the new manufacturing paradigm suggests, graduates must be well rounded and have diverse interdisciplinary skills. This is especially true in the relatively new areas of manufacturing technology that are computer based such as the use of SCADA systems. SCADA systems are a critical area of knowledge for students going to work in industry. As such many engineering and technology programs have included components of data acquisition and control in their curriculum. For instance, Drexel University offers a course in power distribution systems centered around a Reconfigurable Distribution Automation and Control laboratory<sup>3</sup>. Many engineering and technology programs have included the National Instruments' (NI) based LabView™ program into their curriculum for data acquisition and signal processing. Ironically, many graduates who go into industry have very little preparation to perform effectively because their inexperience in understanding data acquisition and signal processing techniques. This is mainly due to the fact that both the hardware and software involved for a fully fledged curriculum in SCADA applications are costly. Subsequently, the cost of training engineers and technologists in this area is very high<sup>4</sup>.

At Northern Illinois University, the Technology Department, aware of these needs in the workforce, has made major revisions in their curriculum. Changes were made after comparing the skills taught in the existing curriculum with those needed in industry. Other considerations included competency gaps emerging from authentic studies such as one carried out by the SME<sup>5,6</sup>. In addition, with assistance from both the departmental industrial advisory board and selected companies, the department embarked on a rigorous project to develop a manufacturing automation laboratory and curriculum that would include data acquisition, signal processing and supervisory control. Detailed descriptions of some of the curricular revisions have been published at various conferences<sup>7-9</sup>. Because of the cost involved in equipping a laboratory with the necessary hardware, an innovative approach which combines low cost NI data acquisition PCI cards, and inexpensive analog and digital sensors and output devices, has been utilized. This paper outlines the development of the low cost SCADA systems as part of the automation curriculum, and the challenges and learning outcomes as reported from student evaluations specifically for this component of the course.

### The Revised Automation Curriculum Incorporating SCADA Applications

The Engineering Technology curriculum in Manufacturing at Northern Illinois University is comprised of a variety of components which include fundamentals such as mechanics, design, and materials; and practical components such as fabrication, machining and manufacturing automation. Previously, manufacturing automation covered robotics, advanced PLC applications, and machine vision. Based upon the advanced needs of the students, it was determined, through discussions with graduates, employers, and the MET advisory board, that the automation curriculum must be altered. It was also determined that the newly designed automation course must include the following components:

- Advanced PLC applications (analog processing)
- Sensor interfacing

- Component manufacturer literature search and selection (voltages, current, and compatibility)
- Pneumatic control
- Robotics
- Machine vision
- Computer-based control and integration through SCADA applications

The automation course is taught each spring semester to approximately 20 students. The course is taught at the senior level, and is designed to integrate theory and operation with an intensive laboratory component. All of the students meet together for the lecture/discussion portion of the class that typically lasts for 2 hours a week. Laboratory sessions also typically last 2 hours a week. The entire first half of the semester is devoted to LabView™ with simple experiments involving programming, data acquisition and signal processing (for both analog and digital signals). The LabView™ session, which culminates with the development of a SCADA system as a project, covers the following areas:

- Introduction to the LabView programming environment
- Developing Virtual Instruments (Vis) and their sub-components (subVIs)
- Program control (case structures, loops, etc)
- Data manipulation (clusters, arrays, graphs, etc)
- Data acquisition
- Data handling and presentation (files, algebraic and statistical manipulations).

The SCADA project involves construction and implementation of a temperature control system. The students are provided with the following:

- A covered and partitioned plastic box (8½ by 7½ by 3 inches)
- A 24 V DC fan
- Analog devices TMP 37 temperature sensor (two each)
- A 12 V DC light bulb (to provide heat)
- Two LEDs ( green and red)
- Relays

The plastic box is used to simulate a two-room house. The students connect the temperature sensors to two analog channels of the DAQ using the NI SCB 68 breakout board. The sensors require 5 V DC excitation which is provided by the breakout board from the DAQ card. The system is set up such that the fans and the LEDs are powered by an external 24 V DC source while the lights are powered by an external 12 V DC source. The light bulb is set to be permanently on in one of the chambers. The students, upon completion of the wiring, develop a user interface using LabView™ that acquires the temperature signals from each of the partitions. Depending on the room temperature, if the temperature difference between the two partitions exceeds a given value, a red LED and a fan simultaneously turn on. The fan blows cold air from outside into the heated chamber causing the temperature to drop. When the temperature is below the set value, a green light turns on. Because the control voltage from the DAQ is only 5 V DC, relays are used to control the operation of the fan and the LEDs. Figure 1 shows a completed box while figure 2 shows the schematics of the project. Figure 3 is a sample of the program (block diagram) to implement the control process. On the front panel, the students displayed

temperature data from each sensor in graphical form. An example of the front panel is shown in figure 4. In addition, the students are required to store the temperature history over a period of time in a LabView™ data file.

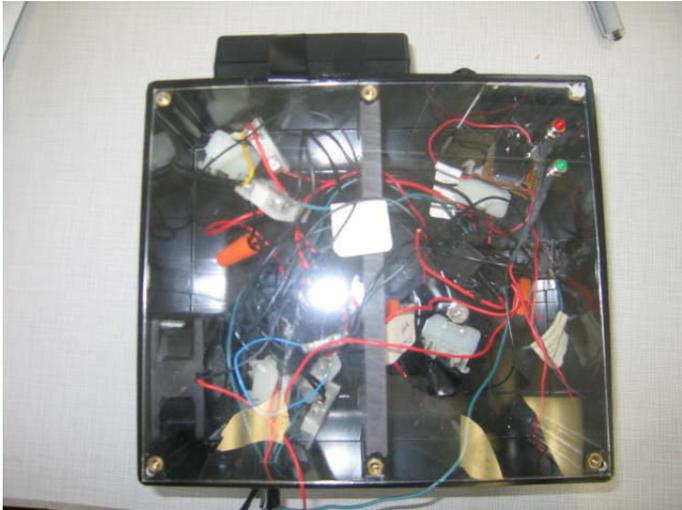


Figure 1. Temperature control system

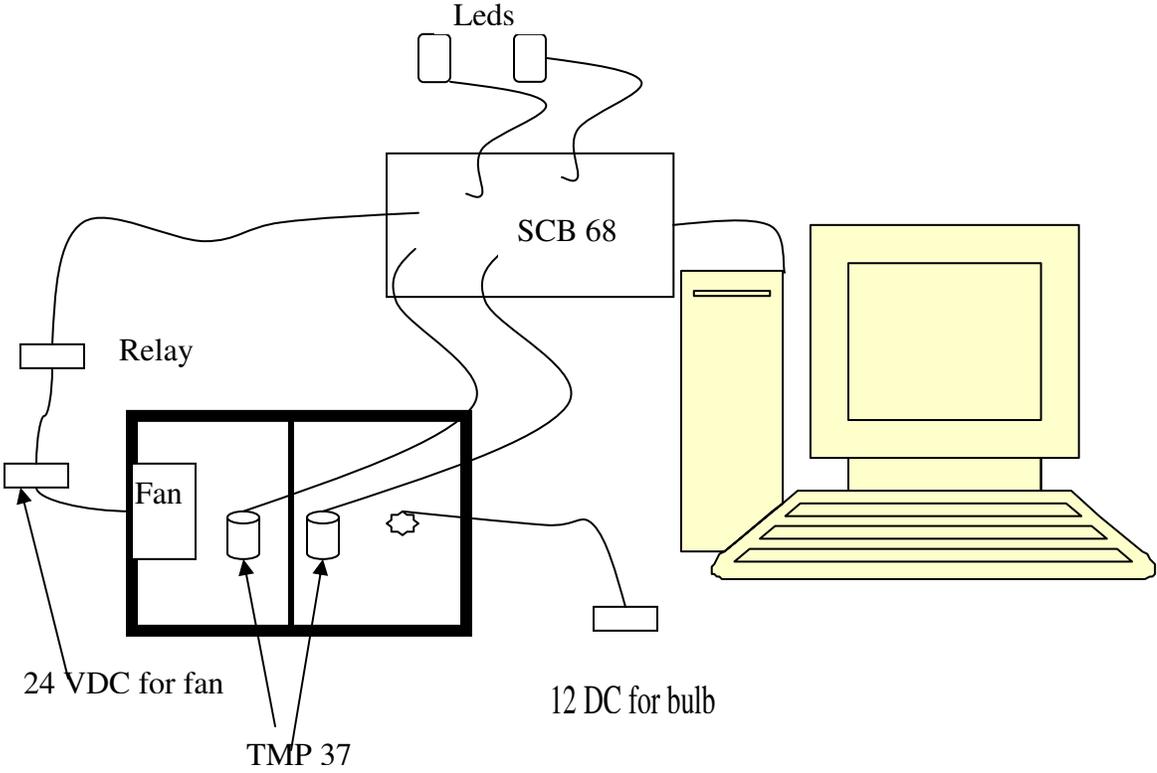


Figure 2. Schematic of the project

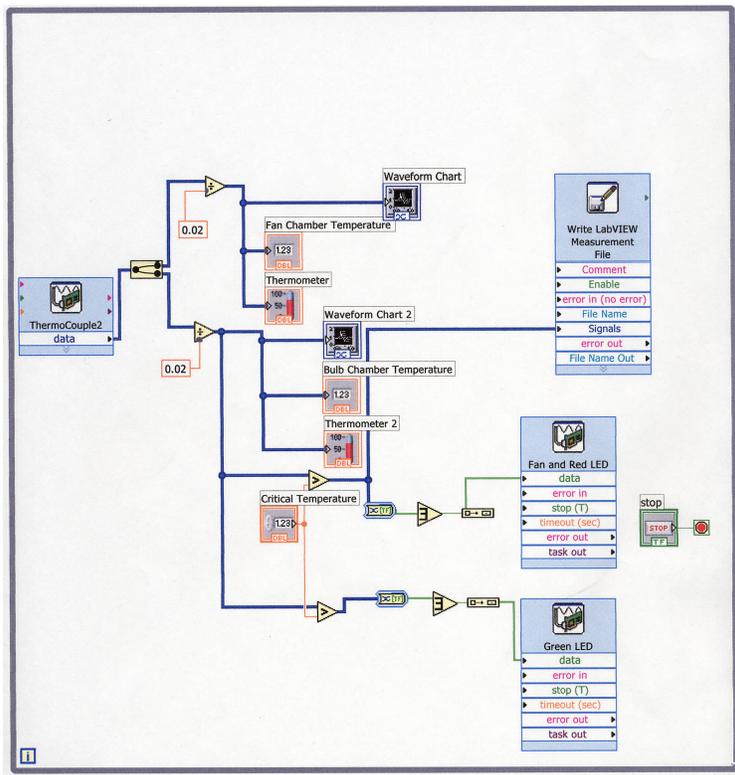


Figure 3. A sample of the block diagram for the temperature control

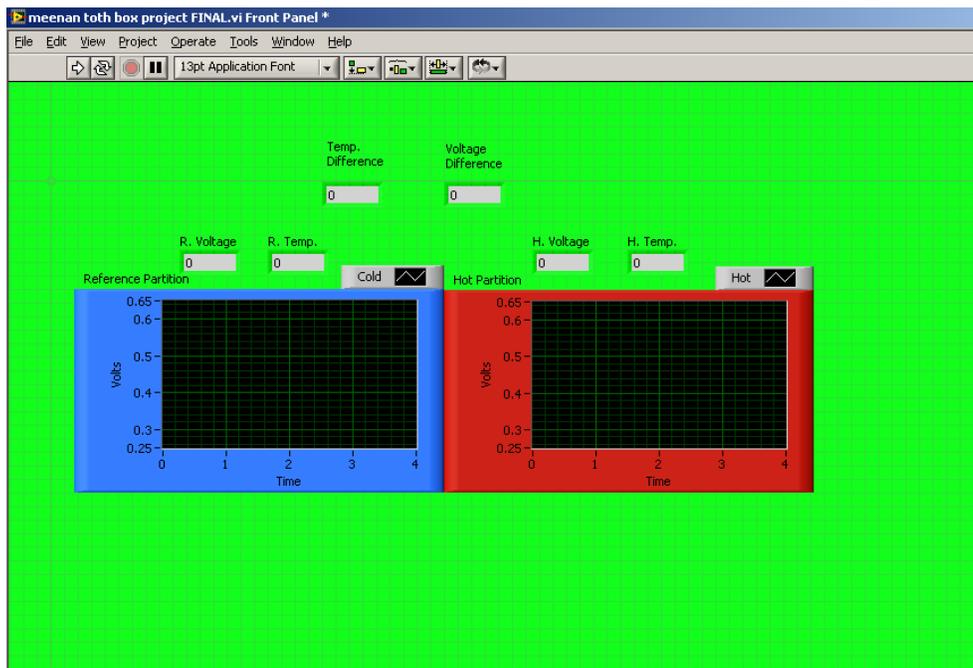


Figure 4. An example of the front panel used to display temperature data.

## Challenges and Learning Experiences

At the end of the first half of the semester, each student group presented their working SCADA system. A ten-question survey was also given to the students to evaluate their learning experiences and outcomes. The survey is shown in the appendix. In addition to answering the ten questions, the students were also asked to make comments regarding their experiences with this project. Table 1 below is a summary of the responses obtained from the survey.

Question #	Number of students responding (percentage in parenthesis)				
	A	B	C	D	E
1	3 (13.6)	6 (27.3)	12 (54.5)	1 (4.5)	0 (0)
2	1 (4.5)	6 (27.3)	13 (59.1)	2 (9.1)	0 (0)
3	2 (9.1)	7 (31.8)	9 (40.9)	4 (18.2)	0 (0)
4	2 (9.1)	6 (27.3)	12 (54.5)	2 (9.1)	0 (0)
5	3 (13.6)	5 (22.7)	14 (63.6)	0 (0)	0 (0)
6	6 (27.3)	8 (36.4)	7 (31.8)	1 (4.5)	0 (0)
7	0 (0)	9 (40.9)	13 (59.1)	0 (0)	0 (0)
8	7 (31.8)	9 (40.9)	6 (27.3)	0 (0)	0 (0)
9	10 (41.7)	11 (50.0)	1 (4.5)	0 (0)	0 (0)
10	2 (8.3)	14 (63.6)	6 (0)	0 (0)	0 (0)

Table 1. Results of the survey

From the results of the survey it can be seen that LabVIEW™, as a new programming language to the MET students, was not so difficult to learn. The majority of the students reported it was generally “averagely” understandable as seen in figure 5. It is a requirement that students in the MET program need to have had a programming language (either in C, C++ or FORTRAN). Using LabVIEW did not seem difficult to them as they all had some previous pre-requisite programming experience.

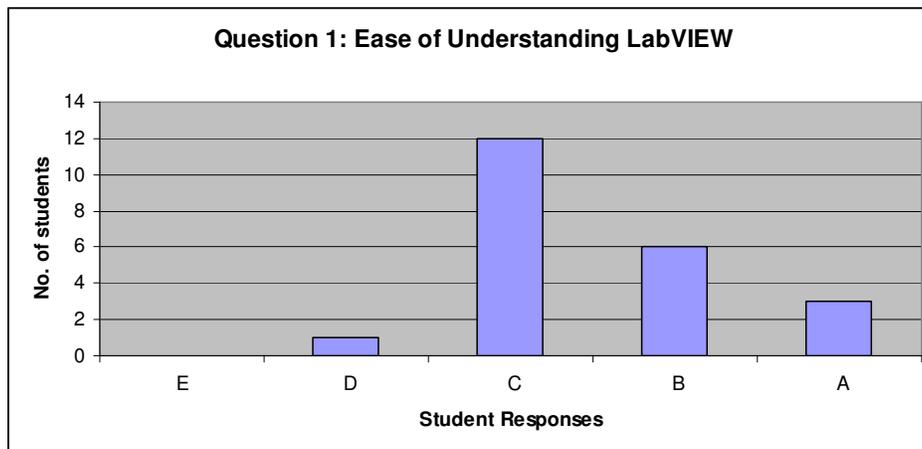


Figure 5. Student response on ease of understanding LabVIEW

Questions 2 to 6 pertained to the way the course was taught and in general most students were content with the way the course was presented. Survey question seven was posed in order to verify whether the students had acquired some appreciation of SCADA systems through this course and the relevant activities. From figure 6 it can be seen that at the end of the LabVIEW™ session, only a little more than half the class were conversant with SCADA applications and their significance. It should be pointed out that the general understanding of SCADA applications before the LabVIEW™ session was very low.

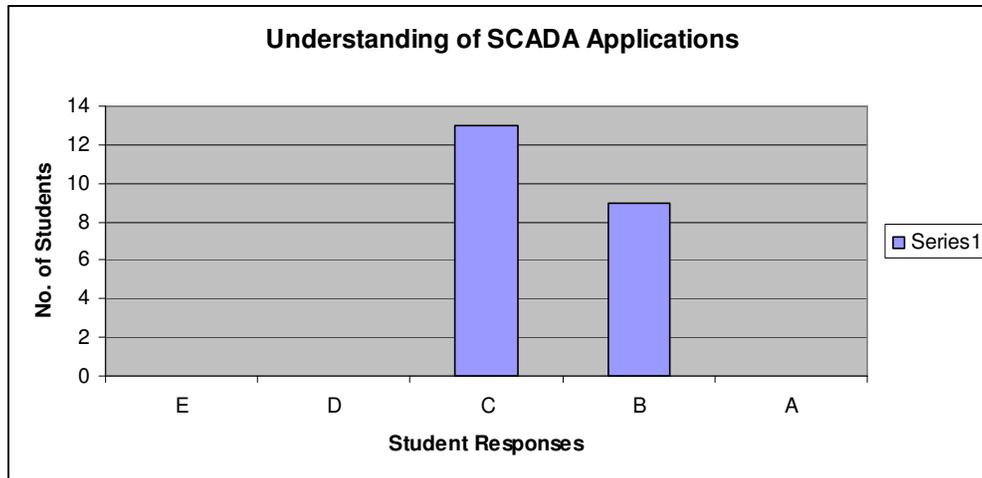


Figure 6. Students appreciation of their understanding of SCADA applications

One important learning experience from this is the fact that most students had not had an experience to work in an industrial environment where supervisory control was extensively utilized, and yet were able to implement a simple system fairly easily. The majority of the students were satisfied with their learning experiences in LabVIEW™ as show in figure 7.

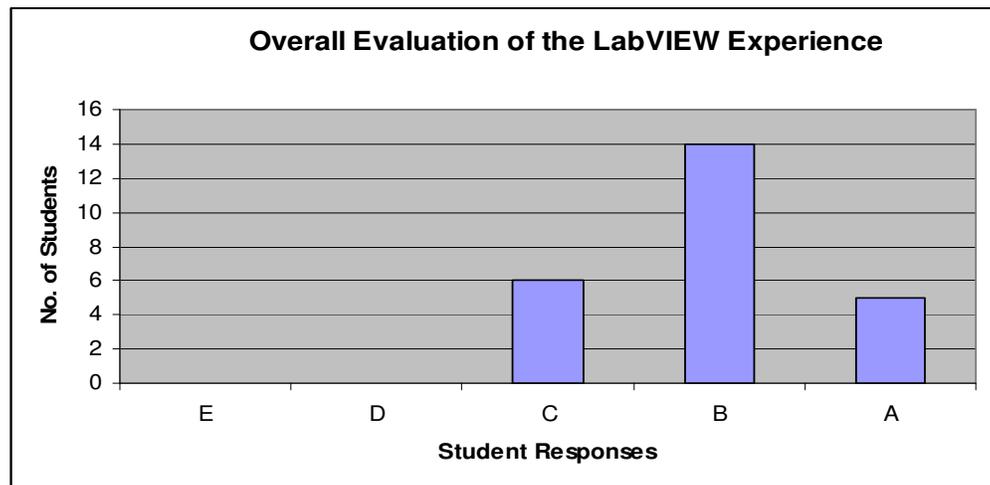


Figure 7. Overall evaluation of student experiences

It should be noted that this is the first time LabVIEW™ was offered as a means of introducing SCADA applications in the automation course and the overall response from the students was very satisfactory.

As for challenges, most students responded that they were able to get their programs done with less difficulty but the actual implementation of the electrical/electronic circuits was very problematic due to the “incompatibility” of the hardware provided. They had to implement extra electronic circuits that they had not anticipated, especially with those involving relays. One student reported that their program took a “relatively short time to implement” but because they had to make “incompatible” hardware work together, it took several extra hours to complete the project. Most students reported that they did not “...expect to wire electrical and electronic components in an automation class ..” but this experience “..prepared ..” them better to work in a practical environment where most times they would have to “... figure out everything for themselves”. More than half the class did have a comment to the effect the project was “interesting”, and that they thought LabVIEW™ should be taught just as a stand alone course.

This project demonstrates that with limited resources, instructors can develop classroom activities that introduce the concepts of SCADA applications. Fully fledged stand alone SCADA systems can be very costly. In this paper, it is noted that the students were able to implement a SCADA application using inexpensive and off-the-shelf components. The approximate cost of each unit including the DAQ system is about \$900. Through this course the students not only advanced their knowledge in automation, but were able to apply other basic fundamental skills required in this field such as electronics, electrical circuits, basic programming, component selection, and basic logic skills necessary for manufacturing automation.

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APPENDIX.

**TECH 423 Automated manufacturing systems**

Evaluation of Part I of the Course – LabView DAQ

The following list of questions are designed to assist the instructor in the evaluation of this section of the course. Your opinions are considered to be very valuable in assisting the instructor to improve future course offerings and the remaining section of the course.

Part I: Circle the letter that best represents your opinion about the question asked.

1. Is LabView programming easy to understand compared to other programming languages?  
A                      B                      C                      D                      E  
easy                      average                      very difficult
2. Was the material presented in a way that interested you?  
A                      B                      C                      D                      E  
Interesting                      usually                      rarely
3. Were the various presentations of material clear to you?  
A                      B                      C                      D                      E  
always                      usually                      rarely
4. Did the course seem well organized?  
A                      B                      C                      D                      E  
excellent                      average                      poor
5. Did the quizzes seem fair?  
A                      B                      C                      D                      E  
always                      usually                      seldom
6. Did the examinations seem fair?  
A                      B                      C                      D                      E  
always                      usually                      seldom
7. Were the materials and assignments adequate in making you understand SCADA applications and automation?  
A                      B                      C                      D                      E  
greatly                      moderately                      little
8. How much did assignments contribute to what you learned?  
A                      B                      C                      D                      E  
greatly                      moderately                      little
9. Was the instructor helpful in the manner he assisted you in your lab assignments?  
A                      B                      C                      D                      E  
Very helpful                      average                      not helpful
10. Considering all of the above, how would you rate the instruction you received in this section of the course?  
A                      B                      C                      D                      E  
excellent                      good                      average                      fair                      poor

.....

Part II: On the back of this questionnaire write down any useful comments about this section of the course. Include things like what you found to be the most difficult and any improvements you would like to see.