Prototype Implementation: An Effective Learning method in Process Automation

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***Abstract*—This paper presents the details of a course activity designed and implemented for the course in Process Automation at undergraduate engineering program in Instrumentation to augment the theoretical concepts. The course activity focuses on integrating basic process devices with plant for automation by developing an industry-like prototype module. The details of the course activity phases are also presented. The outcomes of the activity facilitates in terms of academic performance along with exploratory learning attitude and presentation skills.**

Keywords— ABET, Program outcomes, Bloom's taxonomy, Course project, PLC

I. INTRODUCTION

The term process in an industry refers to a set of well defined sequential tasks to convert raw material into an intended end product. Any and all processes require means & techniques for the measurement and control of relevant process parameters in-order to achieve higher productivity and reliability at an optimal cost. Three theory courses of four credits each, namely process instrumentation, process control and Automation in process control have been introduced in the under graduate curriculum at the fourth, fifth and sixth semester of Instrumentation department in order to impact the students with the inter subject relationship and enable them to progressively gain the application vertical perspective in process control and automation. This in turn helps the students to pursue research and/or career in the said vertical.

Automation in Process Control deals with study of PLCs and its programming. The teaching learning approach adopted for the knowledge transfer and assessing learning outcomes for the said subject involves introduction to automation, introduction to PLC operation, PLC programming and instructions. In order to help the students, learn the subject effectively rather than only study it from an academic perspective, a series of innovative measures are initiated in order to enable the students to gain a practical insight into the subject Automation in Process Control (APC) and also extend the concept learnt to the other process not explicitly covered in the curriculum. The concepts studied in the subject/laboratory can be better augmented by applying the same to a real time application by the introduction of course activity/project. The said approach is a part of curriculum charter which provides a practical hands-on experience of the industrial process.

A typical process plant consists of four major phases that includes sensing, signal conditioning, controlling and actuation. Curriculum design of instrumentation program facilitates the detailed study of these phases under different courses in different semesters namely sensing phase in the course Process Instrumentation (PI), signal conditioning phase through the course Signal Conditioning and Data Acquisition Circuits (SCDA) with lab course at fourth semester, while controlling and actuating phases are addressed through Process Control (PC) and Automation in Process Control (APC) and associated lab courses respectively.

A series of activities were designed at fourth, fifth and sixth semester level which included field survey, implementing controller principles on virtual instrumentation platform like LABVIEW and course project respectively such that emphasis is given to all the phases involved in a typical process plant.

Activity started with assigning a physical parameter to each of the group at fourth semester level and directed for thorough study of these parameter measurements through field visits. In continuation with this, at fifth semester controller principle implementation for an assigned physical parameter was done using LABVIEW and ARENA (system modeling software). With the necessary knowledge of sensors and controllers, a course project has been introduced as an extended activity in sixth semester. The course projects intended for development of prototype for the given complex industrial process sub modules using PLCs as controller.

Organization of rest of the paper is as follows: Section II deals with the details of enhanced learning process, Section III discusses about implementation details and assessment, effectiveness of the activity in Section IV, Section V discusses the experimental outcome (ABET a-k). Finally the results and conclusion are discussed in section VI.

II. LEARNING PROCESS

The details of the course project are presented in this section. The course activity involves the following

- ***Process parameter study:*** An intensive field visit was done by the students at fourth semester level for the subject Process Instrumentation to identify the process parameters for monitoring and control in different application domains. Parameters such as pressure, level, temperature to name a few were assigned to the students. Based on the allotted process parameter, teams should locate the appropriate process industry where the particular process parameter measurement is significant. Study and understand the sensor/transducer used and principle of operation, along with its detailed specifications.
- ***Controller study and design:*** Based on the visit the students had designed and implemented process control module using LABVIEW in the fifth semester level for the course Process Control. This provided a platform for the students to get exposed to different industrial processes and their implementation. Thus enabling them to develop an automated prototype using PLCs during their sixth semester.
- ***Case study model:*** To build the prototype model of the process the students started with literature survey. Survey included detailed study of components and PLC which in turn helps for requirement and compatibility analysis. It involves learning through transactions, journals and correlate concepts connected to theory.
- ***Animation:*** Animation is a pedagogical tool to enhance students learning. Based on the requirement students have to build animation of the process using suitable animation tool.
- ***Prototyping:*** Prototyping for the assigned process was done under two phases. Initially suitable algorithm was developed and after functionality verification through simulation it was deployed onto the model built. This provided, the students an actual feel of the industrial process.
- ***Extended Learning:*** Focuses on core academic learning with detailed qualitative analysis which in turn leads to scope for improvement beyond curriculum.
- ***Report Writing:*** Information collected is organized for meaningful interpretation and analysis and submitted in the form of report, reflecting all the activity details including animation and snaps/videos of the built process

III. IMPLEMENTATION

This section deals with the details of Process execution and assessment methodologies.

A. Process execution.

Execution of the course project involves the following various stages

- ***Team formation:*** Groups were formed comprising four students in each team and team leader was identified. Roles and responsibilities of each student were also defined. Team leader has to coordinate, plan, organize and track the activities within a team. Each and every role within a team was accountable.
- ***Process assigning & understanding:*** Once team formation was done each team was assigned with one process. A typical process plant consist of four major components, they are sensing, signal conditioning, controller, and actuator. Each team was assigned with a typical industrial based process like bottle filling process, liquid mixing process, moving conveyor belt, crushing process to name a few. The students have to make a thorough study of the process and understand how it can be implemented using the conceptual knowledge gained through various courses.
- ***Component selection:*** All the teams are required to study the specifications and operations of available PLCs by referring to the manual/any other resource. Literature surveys made helps the student for drawing out the specifications for the assigned task and appropriately make choice in selecting the component based on their compatibility with the used PLC.
- ***Integration & testing:*** Each team has to develop circuit/algorithm to meet the requirements of the assigned process. Using the selected components and developed algorithm the PLC was programmed and working prototype model of process was built and tested.
- ***Demonstration:*** Students have to effectively demonstrate the built animation of the process. In addition to this, every team has to prepare snaps/videos demonstrating the working prototype model of the process.

Fig.1-4. shows the sample automated prototype models developed during their sixth semester as course project.

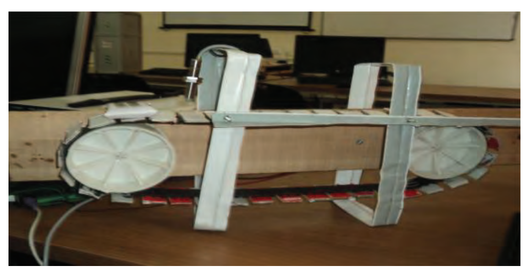

Fig.1. Metal detection on conveyor

Fig.2. Crusher system

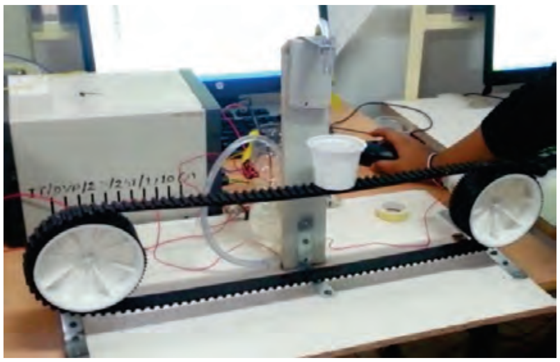

Fig.3. Bottle filling system

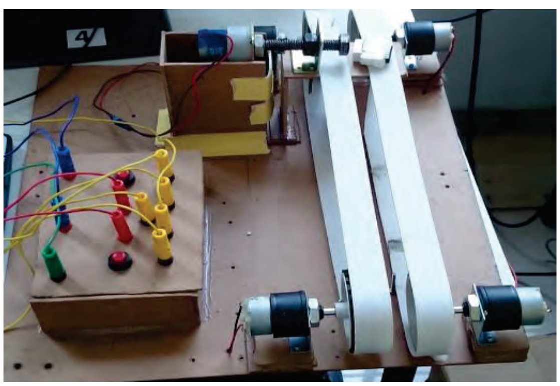

Fig.4. Product bifurcation

B. Assessment

Method of assessing the effectiveness of activity includes student performance assessment, student self assessment and student feedback. Contributions to the activity can be assessed in terms of individual deliverables and group deliverables. The assessment metric/rubric for evaluating the performance of the students is as shown in Table I.

TABLE I. ASSESSMENT CRITERIA

Sl.No	**Assessment criteria**	**Weight age**
1	Literature survey	20%
2	Concept level design	20%
3	Implementation • Animation • Prototype	 10% 30%
4	Demonstration & report writing	20%

IV. EFFECTIVENESS OF COURSE PROJECT

The effectiveness of the activity reflected in the following ways.

A.Reflections of course project through continuous monitoring and feedback

Assessment based on student feedback has been collected by each team as detailed in the appendix and gives the statistics of achievement of each task of the activity. For question 1& 7, an achievement of 97% is observed to justify the learning beyond curriculum as shown in column 1 of Fig.5. Question 3 & 4 related to comfortably working with PLC shows 82% of students could find it easy and comfortable to work with PLC and explore it beyond curriculum for any real time process applications as shown in column 2 of Fig.5. Question 8 & 9 related to improving soft skills and 68% students express as their presentation skills are improved, 42% students express as their leadership qualities are enhanced, 40% students express as their verbal communication has improved and 68% students express as their organizing skills have improved as shown in fig.6.

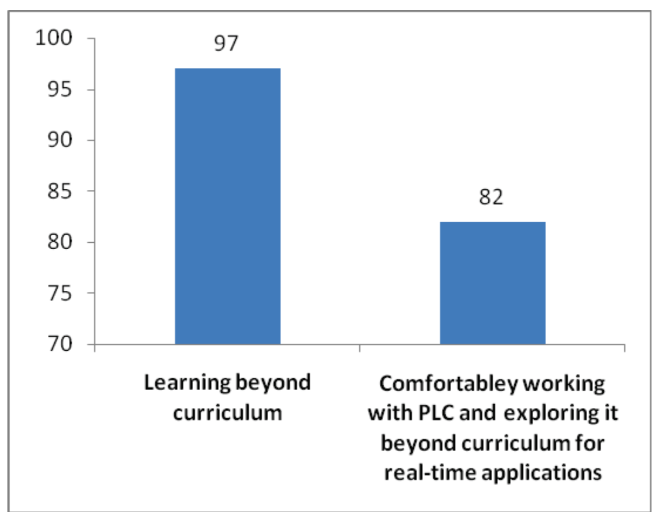

Fig.5. Feedback Questionaire response for Q 1,7 & 3,4

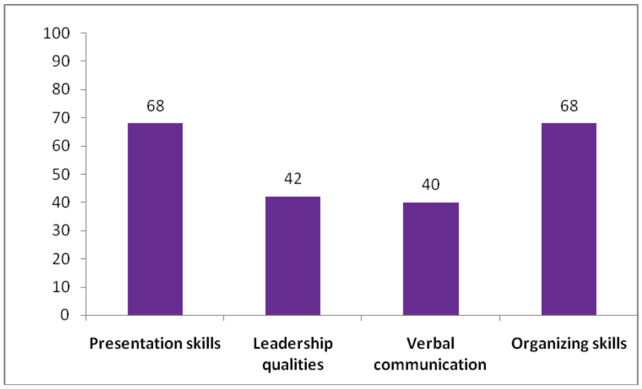

Fig.6. Feedback Questionnaire response for Q8 & 9

B. Reflections of course project in Semester End Examination (SEE)

The effectiveness of the activity proposal has been reflected in the performance of students in Semester End Examination(SEE), where they are exposed to higher levels (L3) of learning as per Bloom's taxonomy [8][10]. The performance of the SEE results for the said subject in the present academic year (2014) is compared with the previous academic year (2013) as shown in the fig.7. An improvement of 30% is observed in number of S grades while an improvement of 34% is observed in number of A grades

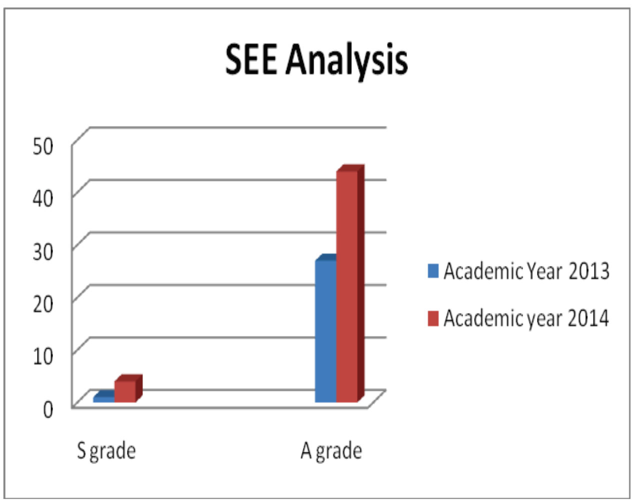

Fig.7. Comparison of results

V. EXPERIMENTAL OUTCOMES AND DISCUSSION

The effectiveness of the course project as a part of a core subject in the identified theme is mapped to the program outcomes a to k of Accreditation Board for Engineering and Technology (ABET) [9] criteria as shown in Table II.

TABLE II. ACTIVITY OUTCOMES MAPPING TO ABET PROGRAM OUTCOMES

Performance Indicators of Course Project	PO-PI Assessed
Perform need & market analysis	
Team formation and defining the roles	d-1A d-1D
Requirement analysis	c-1A
Ability to identify limitations, constraints and assumptions based on available resources.	c-2C
Derive the requirements	
Ability to develop a circuit/algorithm	c-4A
Perform Functional analysis	
Ability to develop system functional block.	c-5A
Choose the proper simulation and modeling tool for functional verification of circuits/system.	c-5B
Ability to verify the desired functionality	c-5C
Conceptualization & Evaluating alternatives	
Ability to develop a circuit/algorithm	c-4A
Ability to verify the desired functionality	c-4B
Ability to explore different approaches to solve the defined problem by carrying out literature survey.	c-3A
Ability to Compare the limitations and advantages of alternative approaches and choose the suitable one	c-3B
Ability to identify limitations, constraints and assumptions based on available resources.	c-2C
Awareness about the importance of learning beyond curriculum using technical library resources, interacting with experts and participating in technical events.	i-1A
Embodiment Design	
Ability to validate the obtained results.	i-1A
Ability to use EDA tools for modeling and simulation	c-5B
Detailed analysis & Simulation.	
Choose the proper simulation and modeling tool for functional verification of circuits/system	ITOE(k)-4A
Prototype development & final presentation	
Ability to verify the desired functionality	ITOE(g)-1A
Ability to write clear and well organizes project reports.	ITOE(g)-2A

The said course without presently adopted pedagogical techniques addressed only a and g in previous academic years while through this activity along with a and g , c,d,i k were also addressed and attainment is as shown in figure 8

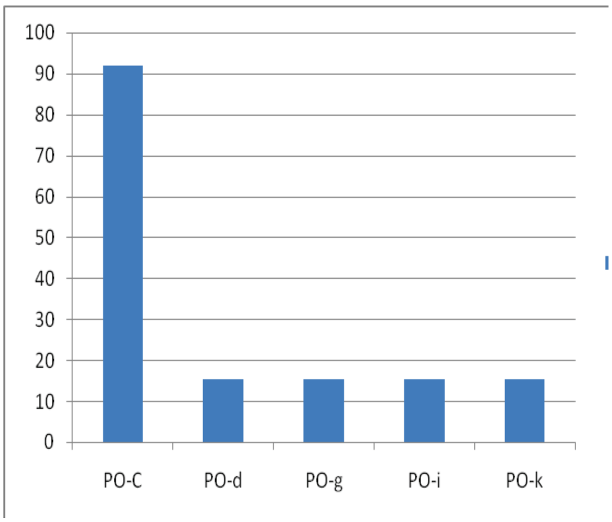

Fig.1. PO Attainment for the Process Automation Course

VI. CONCLUSION

This paper presented the design, delivery and assessment of a course activity for the course Automation in Process Control students at 6th Semester. The activity designed strengthened process control course by enhancing the learning. The metrics and the techniques adopted for the assessment of the learning outcome have been listed and the results are presented. The overall outcome as seen from the result analysis clearly indicates that the approach adopted has indeed significantly been encouraging in terms of the holistic student development. The most prominent positive outcome of the experiment is that over 90% of the students have clearly indicated that this has given them a very good opportunity to evaluate, work on and improve their verbal as well as written communication skills apart from helping them in connecting the theoretical concepts to practical applications.

This is to observe that the innovative approach adopted has indeed significantly effective in improving the overall teaching learning process, encouraging the teachers and the students to extend the same to the relevant courses in the curricula program and also identified problem definitions can be taken up as a capstone project in senior semester.

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