

# Integrating Research Experience in Project based Learning

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*Abstract— A lot of emphasis is being placed on the research experience at undergraduate level both by institutions of higher learning as well as industries focusing on research & development (R&D). This requires a twofold effort. First is to develop research competency in teaching faculty so that they can act like mentors and second is to develop a process so that the students develop basic research skills through practice. Parallels can be drawn between the Engineering Design (ED) process and research skill building process in terms of creativity and problem solving. Similar to the ED process, a converging and diverging process can be used to creative problem research. This process has been introduced as part of a course project at the third year level for the course Programming Industrial Automation Systems. This paper tries to demonstrate the process through which a structured literature survey is carried out by the students leading to a variety of research problems. This process is carried out as a team activity. Research assignments have been integrated in the course, which requires students to find information on automation related topic using both print and electronic resources available at the college library and on the Internet. Aiming to foster the development of technical information literacy and communication skills, the students are required to prepare a report based on a specific set of guidelines, followed by implementation of the solution and oral presentations of the topics researched. A lecture on the subject of identifying and using information resources is included in the syllabus. Preliminary results of the study are presented along with directions for designing and implementing an enriched curriculum for Automation course.*

Keywords: Research & development ; Engineering Design process; Research skills; creativity; Problem solving ability; Automation; Programming Industrial automation Systems; structured literature survey; information literacy

## I. INTRODUCTION

Engineers work in an environment having scope for innovation and problem solving abilities. They need to equip themselves with the skills for problem-solving, communication, teamwork, self assessment, change management, lifelong learning and so on. It is the responsibility of engineering educators to design special activities and methodologies which are consistently in line with ABET Engineering Criteria 2000, to develop these desired skills [1]. Activities can be introduced at undergraduate level aiming at developing of basic research

skills leading to critical thinking, idea generation , finding innovative solution to the problem encountered and demonstrating communication skills. Students can acquire skills most effectively through good practice and feedback for any corrections required. Through carefully designed active learning practices, students undergo extensive practice in the application of those skills and get regular constructive feedback from mentor for improvement in turn leading to achievement of targeted skills. People with such higher skills are in high demand as compared with people having only technical skills. This is the need of hour in industries as well autonomous institutes of higher learning. Teachers also need to grow as mentors in this process and gather similar skills. The activities can be specially designed to address this issue in a systematic way through proper planning by teachers involved. Hence there is a need to develop a pedagogical culture based on research methods in order to equip students with those skills for their successful career ahead and the focus should be on the ways of delivering them effectively [2].

The activity can be conducted group-wise to ensure peer learning and develop inter-personal skills also. There is a need for assessment strategies to evaluate individual competencies as well teamwork abilities. As the activity is based on problem solving, students deal with case-study analysis which helps them study the problem in more depth. Cases study analysis proves to be very effective for developing research skills in students as they study the problem with respect to a context [1]. Empirical findings suggest that a research-based teaching model engages students more productively in their regular theory and laboratory activities and develops deeper critical thinking [2]. Activities based on research introduced at undergraduate level can create very good exposure on scope of research ability and initiates interest in students to take up higher studies and career in research and development (R&D)[3]. It is seen that training on research skills has been rewarding for students in technical professions also. Improved teaching practices can aid research activity and improved research ability of teachers can lead to better teaching practices [4]. Research skills are required by everyone to have a successful career either in academics or in industry. Information literacy skills need to be acquired by students in order to differentiate sources of information as authentic or unauthentic and understand the importance of referring standard journal articles as compared with information content

available on internet. Research and informed-based teaching is very well accepted by experts to foster skill development of teachers and students[4]. Even though engineering teachers believe that the soft skills are very important for overall development of students, they fail to design activities that can foster development of research skills in students

Identification of problem itself is an important stage of research process involving lot of analytical thinking with inquiry based learning [3]. In order to make students undergo this part of research process with the objective of developing higher skills, we have designed a Research based Teaching – Learning model. Here, we propose a project based activity involving problem identification through research methodologies and building the process for solution for the identified problem and finally the implementation of solution. Under this activity, problem search is regarded as an important process as research methodologies involving a structured literature survey through convergent and divergent principles of search methods as per engineering design process are employed. Students do survey of latest published journal articles and other authentic sources of information to arrive at the problem. Through the activity, students get an exposure regarding the identification of authenticity of resources while doing problem search [3]. Teachers undergo the activity along with students during every phase of the activity, develop research aptitude skills and thus improve their teaching skills. Hence the activity, if conducted regularly in every semester can foster development of research skills of students and teachers involved in the process in a phased manner. This can definitely prove as an aid for improved teacher-student interaction throughout the process, which is many a times missing in conventional classroom teaching.

## II. DESIGN AND IMPLEMENTATION OF RESEARCH ASSIGNMENT

The proposed activity of literature survey based project activity for problem identification was taken up as a course project at third year level under the course Programming Industrial Automation Systems [PIAS] for the batch of 36 students. The proposed activity aimed at drawing parallels between theory for the course PIAS and the practical sessions in Automation lab. The activity was divided into three phases namely problem search, designing process flow and implementation using Programmable Logic Controller (PLC) hardware and software. The course PIAS is made up of six different chapters having a set of sub topics in each. Each student group was allotted with a specific chapter on lottery basis. Hence students need to follow the divergent and convergent process for analyzing the identified problems and short listing them in several iterations as per engineering design process. Students used the segregation methodology for identifying the scope, potential and constraints under each iteration before converging to smaller set of problems and finally to a single problem to be solved. In order to do good

research, there is necessity for creation of good questions, nothing but selection of an appropriate problem [1,2].

Students seek out information from sources such as textbooks and journal articles to survey for problems in the assigned domain related to PIAS course syllabus. Students followed inquiry based learning approach to explore an issue in assigned broad area and follow an iterative process to narrow down to a specific problem of interest. Students used divergent and convergent search techniques referred in engineering design process for problem search in the assigned broad area. They were able to scan for a variety of problems through divergent process initially and later converging towards lesser number of problems by limiting the scope and following feasibility constraints. Students used a set of research questionnaire while doing diverge and converge processes. This process of convergence and divergence is iterated in successive steps before they finally identified the problem to be solved. Every phase of the project activity was documented neatly by students as they progress through the activity. Students were given a set of guidelines for reading research articles and writing summary on their own. Students collected the information from the shortlisted papers by answering standard research questions and using keywords.(4) Students further described the problem with a refined problem statement giving complete insight into the problem under consideration. Students could identify key words in the problem statement that helped them to identify the resources needed to solve the problem.

Students were able to make connections between the problem statement, the identification of required technical knowledge, and the problem solution. The collected data from survey done shows that students took very good interest in problem search activity. Student teams could arrive at problems related to case studies like Unmanned railway gate control, Lift control mechanism, Coupled tank control in process, Boiler temperature Control, Conveyor control for material handling system etc. They used algorithms and flow charts to design the flow of process to solve the identified problem. Later they verified the solution using PLC simulation software and finally implemented and demonstrated the solution using PLC hardware. The activity involving three phases namely problem search, designing process flow and implementation using hardware and software was evaluated for 30% of the total internal marks. Problem search phase based on literature survey was given higher priority by assigning around 60% of the total time allotted and the remaining 40% used for second phase of designing process flow for the solution to the identified problem and third phase of implementation process.

## III. TEACHING STRATEGY

As teacher is aiming at developing of the critical skills of students, soft skill development is included as an important objective under the course syllabus. A session of 4 hours

duration was planned and included in the syllabus to explain to students the objectives set , structure, scope, schedule, evaluation scheme, outcomes and benefits at the beginning of the activity. The teacher in the whole process acts as a guide rather than instructor. The teacher’s strategy was firstly to convince students of understanding the relevance of undergoing the activity, which is quite different from regular project based activity [1]. Students were provided with a set of standard guidelines for reading IEEE papers for problem search. Later they were given inputs regarding the tools that can be used for design of Process flow and finally implementation.

During the activity monitoring, mentor was responsible for clearing their queries through demo of examples and by supplying the relevant study material. Students got the necessary inputs through regular interaction with mentor as per plan. Here the objective of teacher is to promote inquiry-based learning (IBL) rather than problem based learning [3]. Students develop any skill through hands on practice only, not by oral presentations or undergoing demonstrations. Hence the teacher involved needs to constantly motivate students to achieve the skills and provide constructive feedback on their performance. It is a challenging task for teachers to develop research skills in students as it is linked to attitudes and values which cannot be easily measured. Teacher needs to relate this skill development activity to their professional career. Teacher, as mentor needs to keep track of the progress achieved by each team by constant feedback and follow up as per schedule.

#### IV .ASSESSMENT

Evaluation was carried out based on the designed rubrics through two review processes .As it was a group activity, they were able to short list 3 to 4 relevant papers in the assigned broad area to identify the problem in a group of 3 students for the total batch size of 36 students.. Thus each student was engaged actively in problem search phase and was able to review one research article individually and summarize. . Rubrics were designed for the activity for the three phases accordingly to have weightage of 60% of total marks for I phase and 40% weightage of marks being shared by the other two phases. Assessment strategy was mainly to emphasize on research techniques being used by students for problem search as compared to developing a solution for the identified problem. Assessment rubrics was designed to evaluate their performance in terms of marks scored as well based on demonstration of higher skills as per the objectives set. There was an equal importance given to evaluation of both technical competency as well higher skill developments. The stress was to evaluate the individual competencies as well team competencies in order to make students understand the need for acquiring team work skills.

It was a challenge for teachers to design rubrics to extract information on attainment of skills which cannot be easily quantifiable. There is requirement for measuring the level of

attainment of soft skills based on the methods adopted for problem search, the way problem is solved, documentation of work ,preparing their own reports, teamwork skills demonstrated and self-assessment and stress management techniques followed [2,4] Students can be made to carry out self assessment through reflection process.[2] Students can review their progress on their own through the questionnaire supplied by mentor and improve themselves to achieve desired objectives. This is indeed a helpful approach supporting life-long learning.

#### IV. RESULTS AND FEEDBACK

Project-based learning offers a wide range of benefits to both students and teachers [5]. This was evident from the performance of students as well their response collected against the questionnaire for the activity to measure their satisfaction. The table I & II shown below explain the performance of students measured through continuous evaluation. Table I compares the performance of students in the two activities, i.e theoretical written tests contributing to 60% and survey based project activity contributing to 40% of the total internal marks respectively .It is evident that students took good interest in research based project work activity as compared with theory tests. Students performed better in literature survey based project activity as compared with written test activity. This is evident even from the bar chart shown in fig 1.0 based on the data collected in Table I. It can be noted that number of students who have scored less than 40% has drastically reduced from 20 to 6 students while comparing the two activities.

Further, the data collected based on results of performance of students through project reviews and also the feedback collected through the questionnaire is shown in table II. It is evident that through research based project activity, students could achieve higher levels of learning in line with ABET criteria addressing e, f, g, i, j and k outcomes better as compared with mere project based learning. The tabulated data and the corresponding bar graph presented in Fig.2.0 reveals that students have realized the benefits of undergoing the activity. The positive response got from students has motivated faculty members to refine the methodologies followed in the activity to improve the effectiveness of learning.

Table I. Comparison of performance of students in tests and survey based project activity

Activities / No of students falling in score ranges ( %)	(below 40) %	(40 - 59) %	(60 - 79) %	(80 - 100) %
Marks through Written tests	20	30	40	10
Marks through Survey based Project activity	6	35	45	14

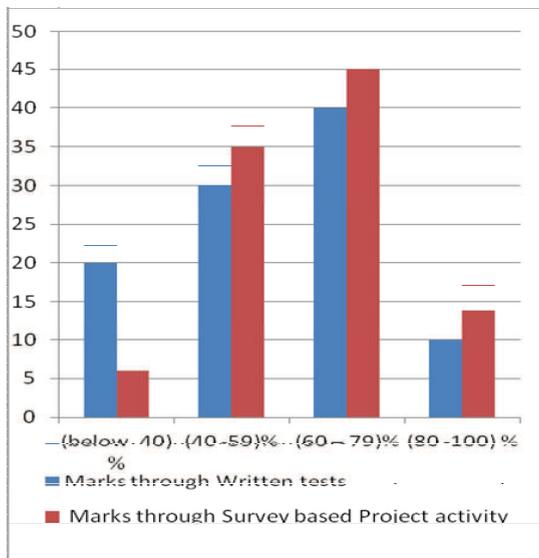


Fig.1.0 Bar chart of the data collected in Table I

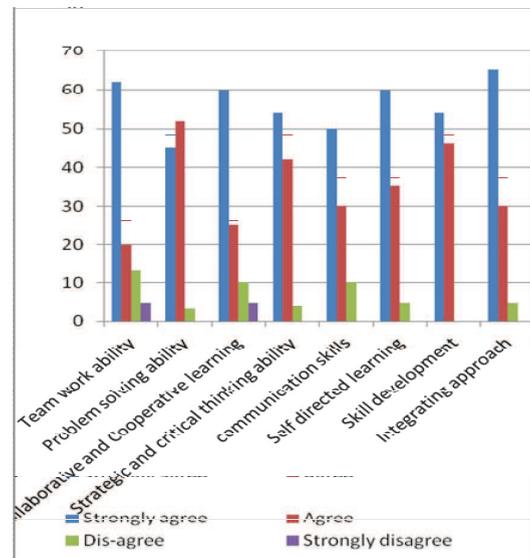


Fig.2.0 Bar chart of the data collected in Table II

Table II. Feedback on effectiveness of the Project based activity

Factors measured based on Feedback and Performance	Attributes (%)			
	Strongly agree	Agree	Dis-agree	Strongly disagree
Team work ability	62	20	13	5
Problem solving ability	45	52	3	0
Collaborative and Cooperative learning	60	25	10	5
Strategic and critical thinking ability	54	42	4	0
communication skills	50	30	10	0
Self directed learning	60	35	5	0
Skill development	54	46	0	0
Integrating approach	65	30	5	0

## VI. CONCLUSION

We studied table of data and graphs showing the feedback of students on the activity carried out as well the performance of students in terms of the competencies demonstrated. Thus faculty members involved got motivated through students volunteered participation and demonstration of higher skills. As it was the activity done for the first time, there was room for improvement in the assessment methods to be used for measuring higher skills attained by students.

And the objectives of the activity cannot be met through one such activity in single semester but on regular basis under every semester from III year of engineering in one or more of the courses offered. Such an activity planned in every semester can definitely help students strengthen these skills and knowledge in a phased manner. This activity has proved to be very essential in making teachers and students aware of the importance of acquiring essential research skills along with technical skills through the project based learning activity. We are in the process of developing standardized practices and guidelines to carry out similar activities in future, for other courses under Automation & Robotics curriculum. These activities certainly improve the development of organizational and self management skills of students and teachers.

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