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RESTRUCTURING OF EMBEDDED SYSTEM DESIGN COURSE: MAKING IT INDUSTRY COMPLIANT

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ABSTRACT- Embedded System Design, the most challenging course of electronics engineering has always been appreciated and well acclaimed by the students of electronics and its related branches of engineering. Embedded system, being a product of multiple application domains, necessitates skilled man power to be well designed and tested in every important aspect of both hardware and software. In the current industrial scenario, the requirements are even more rigorous and highly demanding and needs to be to be on par with the advanced technologies. Fresh engineers are expected to be thoroughly groomed by the academic system and the teaching community. Graduates with the ability to understand both complex technological processes and technical skills are increasingly sought after in today's embedded industry. So, the need of the day is to restructure the under-graduate course- both theory and lab practice along with the teaching methodologies to meet the industrial requirements. This paper focuses on the importance of such a need in the present education system.

Keywords: Embedded system design, Industry requirement, syllabus restructuring, Project-based learning, and teaching methodology.

I. INTRODUCTION

Embedded system is a computing system which is application domain specific. Application domains are enormous starting from Nuclear Power Plant, Avionics, Automotives, Medical Instrumentation, Multimedia, Telecommunication to wide spread Consumer Products. Embedded system as an end product either receives commands through human interface or is highly interactive with the external environment. It infers that the embedded systems are non real time or real time in nature. In real time embedded systems, the environment dictates the system how to respond back to the environment[1]. It must have sensors at the input end to receive the sensory signals after being digitized, process it as per the control algorithm written for the application and actuators at the output end to actuate the mechanical parts those are directly connected to the environment. Based on the application, the requirements are listed, the specification is defined, the components are selected and the hardware board is designed and tested. Based on the level of computational capability demanded by the application, a suitable embedded OS is chosen or is customized. The application program is developed and tested with an Integrated Development Environment (IDE). Once the compiled code is ported on to the hardware board, it is required to be tested rigorously as per the specifications. After the system is integrated and thoroughly validated with all its intended features, it is shipped to the market [5, 6]. Looking at this brief process flow, it can be predicted about what level of complexities and challenges is involved in embedded system design. So to design and develop such systems, the industry requires widely exposed and immensely skilled engineers who can brain-storm their ideas and carry out their jobs at ease with good technical know-how from the day one. Engineers should be able to contribute to the field of technology expansion. This is possible only if the academia produced quality engineers are industry ready from the campus itself [2]. In this regard, the current need is to restructure the syllabus, well equip the laboratory and refine the teaching methodologies.

This paper is organized as follows - Section II deals with industry-academia interface, section III highlights the industry-academia needs and expectations, section IV addresses the mismatch issues, section V speaks about the embedded system design course with the curriculum and trends in industries, section VI suggests restructuring of the syllabus, lab updation and modifying teaching methodologies and the paper concludes with section VII highlighting the need for making the course industry compliant.

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II. INDUSTRY-ACADEMIA INTERFACE:

A productive and interactive interface between academia and industry in the current scenario of knowledge economy is a critical requirement. The industry academia interface is all about knowledge, experience and technology transfer. Universities and industries have been operating in independent domains for long period of time earlier to this, are rapidly joining hands to create miraculous technological developments. There is a visible paradigm shift in response to growing complexity of the industrial environment [7]. The industry has become more and more aware of the vital linkage between the academic system and the corporate productivity. As much as academic institutions focus to produce well-groomed engineers to industry, the industry needs to involve itself more into the activities of the institutions for improving the quality of human resources. The domains in which industry-academia interaction is possible are:

- Industry inputs to design the course curriculum based on industry requirements.
- Industry support to promote academic research activity for technology development.
- Industry trends and practices.
- Source for external projects sponsored by companies.
- Consultancy projects.
- Academic initiatives in solving specific industry problems.
- Laboratory advancement and utilization by industry.
- Continuous education programs by experienced industry people for knowledge sharing.
- Concept of industry-institute partnership cell.
- Industrial visits.
- Joint Faculty Development Programs.

III. Industry- Academia Needs and Expectations

The expected time frames of the industries are immediate and investment is directed towards effort that promises result-oriented solutions [7]. Industries are reluctant to invest in technology R&D which has either long-term or unclear outcomes. Academic involvement is required in minor technological innovation or modification towards new implementation. Academic systems value the autonomy of the individual researcher and prefer strongly for working towards creation of knowledge in specialized domain. The active participation of the industries is required in course curriculum framing in the effort of producing skilled engineers to comply with the need of the industry [3]. For academicians, the primary focus of interest is a problem that has higher intellectual challenge. Technology development initiatives which involve the understanding and exploration of a concept and alternative methodologies related to process and design improvement could be of considerable interest.

IV. The 'Mismatch Issues' to be Addressed

There is a need to bridge the large gap between industrial needs and the execution process of the current academic systems.

- For academia, the technology development quantifies to conceptualization and execution coupled with validation at the laboratory level.
- For industry, it is important to translate the lab validated concept into a commercial proposition.
- The industrial R&D should be focused on technology development where lab models are scaled up and converted to commercially viable products or processes [4].
- Evolving a lab proven idea into an implementable technology is a kind of effort which the academic community does not appear to be fully geared to.

V. Embedded System Design course: a Case Study

Embedded system design is a course taught at the higher semesters considering the fact that, students have adequate background knowledge on microprocessor/microcontroller and programming. The course provides conceptual knowledge in a generic way rather than being more application oriented as it is required.

A. *Curriculum Provides:*

- Basic concept knowledge on embedded system, hardware and software requirements.
- Knowledge on various processors used in embedded systems.
- Abstract knowledge on components selection.
- Serial and parallel port interfacing.
- Memory allocation and management.
- Serial and parallel communication protocols, their features and working.
- Different methods of Input/Output (I/O) operations.
- Writing device driver pseudo-codes.
- Multithreaded embedded software environment.
- Requirement of a Real Time Operating System (RTOS).
- Interrupt handling and task scheduling of RTOS.
- Various scheduling algorithms and context switching.

B. *Industry Trends:*

- Model based design
- Analytical versus Computational models.
- Critical versus Best-effort design.
- Guaranteeing safety versus optimizing performance.
- Dealing with heterogeneous multi-core platforms to ensure performance.
- Developing hardware independent parallelizing software.
- Hardware and Software co-design.

VI. RESTRUCTURING THE SYLLABUS:

Embedded system design an applied course of electronics engineering requires computational, conceptual and analytical acumen with equal proportions. The new structure of the syllabus can refer the six levels of 'Bloom's Taxonomy' to arrive at clearly defined course outcomes as well as keeping in view the industry requirements [4].

'Bloom's Taxonomy' Levels are:

1. Knowledge— memorizing facts.
2. Comprehension— explaining concepts.
3.Application—applying knowledge to solve straightforward problems
4. Analysis—solving complex problems, developing process models and simulations,
5. Synthesis—designing experiments, devices, processes, and products.
6. Evaluation—selecting among alternatives and justifying the selection, optimizing processes.

A. The new syllabus could be:

- Features of embedded systems, Design flow, Hardware and Software components, Introducing IDEs, Simulators, Emulators and various industry standard development tools with their relevance in embedded system design.
- Various processors and controllers currently available for embedded applications and their features, Various memory and peripheral devices used in embedded products with their specific purpose.
- Classifying embedded systems based on scale of computation, selecting appropriate processor, memory and peripherals for specific applications as case studies, processor and peripheral interfacing methods based on serial or parallel communication, various I/O operation methods with respect to different application examples.
- Serial/ parallel communication protocols, their features and developing applications using each of them. Developing device drivers for real world applications.
- RTOS concepts, kernel services, task scheduling and interrupt services, developing applications with and without using RTOS, analyzing the performance parameters.
- *Self study Component:* System modeling and Hardware-Software co-simulation, Automatic interface generation, Hardware and software partitioning, Functional partitioning and optimization. Low power embedded system design [5, 6].

B. Laboratory Updation:

To make the students conversant with the practical experimentation and prototype system design considering every aspects of hardware and software design for various applications and validate the concepts taught in the class-rooms, the embedded system design course should be framed with the lab component attached to it.

A well set up embedded system design lab requires:

- The lab should be well equipped with adequate number of computers.
- Various development boards with built-in RTOS should be there for the students to comfortably work on different projects.
- Lab should have development software and IDEs to develop and debug various experiments and projects.
- The board support packages and library functions should be well documented.
- The faculty and lab support staffs should be well trained about the work flow [7].
- An exhaustive list of experiments and project ideas should be available as per the industry demands.
- An industry standard lab manual should be available for students' perusal.

C. Improving Teaching Methodology:

In the current world of information networking, students are exposed to many open sources, those provide good subjective contents. So there is a need to improvise the class room teaching methodology to provide an innovative and stimulating learning environment where students can prepare themselves to excel in career and life [3]. Teaching could be with the traditional chalk/Pen and board or with power-point presentation. But while delivering the lecture, effective learning strategies should be followed.

- Introduce each new topic by relating it to previously learned concepts and real world application, probably starting with an illustrative case study.
- Formulate analytical questions and carry out steps in deriving problem solutions.
- Formulate small design problems, decompose to problem modules and assign to student groups to brain storm on the probable solutions.
- Brief out every what, why and how at the end of every class and clear out the confusions.

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	65 students (I Year)	145 students (II Year)
Subject Competency	78	90
Problem Identification	40	92
Hardware/Software Design	75	90
Trouble Shooting	80	95
Team Sprit	90	92
Communication/ Presentation Skills	92	94

- Information is there, but it is required to fine-tune it on the conceptual clarity in a more demonstrative way.
- Formulate and provide clear instructional objectives as study guides and test materials.

D. Project Based Learning (PBL):

PBL is the most innovative way of teaching, which enables students gain knowledge and skills on the courses learnt. It helps them develop analytical capabilities, designing and debugging skills, thus helping them to keep pace with the current trends. It sets up a challenging environment among the student community and helps them think beyond the course curriculum.

Embedded System Design course deals with solid state devices, sensors and actuators. It is a subject with strong scientific foundation. The course should be an appropriate combination of both. Students should be assigned with projects as a part of their lab exercise [4]. The assigned projects should provide a learning experience to the students and make them understand the core concepts, by application of their acquired theoretical knowledge.

On an experimental basis, PBL was implemented in the institute for a group of sixty five undergraduate students in the Embedded System Design course. The students were made to work on projects selected from a predefined list of executable projects. This initiative helped the students have an in-depth knowledge of the processor and its working and also enabled them to analyze the outputs in several ways. They also had the opportunity of demonstrating, executing and exhibiting their projects to other students and faculties.

As an improvement to the PBL method, another group of hundred and forty students were given the freedom of choosing their own projects. This gave a wider scope to the students and it was fascinating for the staff to see the various ideas the students came up with. This initiative gave the students an opportunity to survey the different processors available, identify the appropriate processor with its evaluation board, external modules and develop software for the specific designed application using various communication protocols. This initiative of making the students work on a project helped them gain knowledge on different developmental platforms and also helped boost their confidence level about the applicability of the course. Apart from this, their team spirit, leadership qualities, documentation capabilities and communication skills improved to a larger extent.

A post-project review was conducted for the groups of undergraduate students to investigate the effectiveness of PBL. The competency level of the knowledge and skill gained (in percentage) over the duration of the entire course is shown in Table 1 and figure 1.

Table 1: Competency level of the students over the two years of course

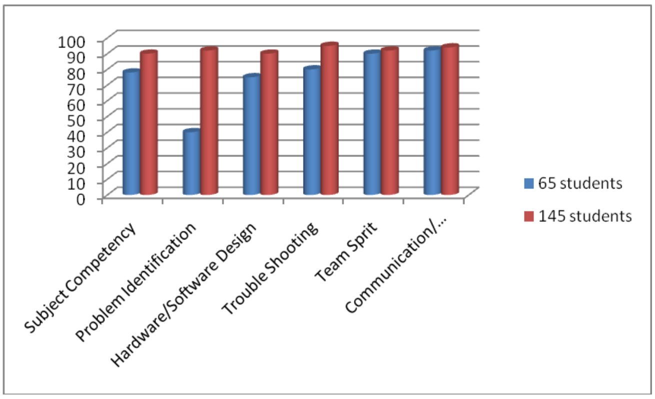

Fig.1: A comparison for the two batches of students in their competency level

VII. CONCLUSION

In the recent embedded computing domain, smaller, faster and superior embedded devices require thorough engineering knowledge and practical acumen and exposure. The lack of adequately trained engineers may cause fragmentations and inefficiencies in product designing and implementation. There is a need to revamp the course curriculum to make it more effective and enable the graduates of this domain to be industry ready. PBL strategy as a pedagogical tool for embedded system education targeting for undergraduate engineering students is a sure way of motivating the students to integrate and formulate the multi-disciplinary knowledge gained throughout their undergraduate courses. An effort to identify and implement PBL has been made in this paper along with modification of

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the syllabus, lab exercises and teaching methodologies to make the graduate industry compliant.

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