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A Methodology for the Development of Competencies Required by Industry

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Abstract: Conventional methodologies for teaching engineering courses are facing problems to address the challenges posed by the industry. Problem-based learning is an attractive solution with certain limitations. This article integrates the problem-based learning with contents-based learning. Contents-based learning only addresses the technical skills. Problem-based learning addresses the technical as well as the soft skills. The proposed methodology is implemented by taking the Digital System Design course as a case study. A comprehensive assessment through analysis of quantitative data proves viability of the proposed approach.

Keywords: Problem-based learning, Student outcomes, Soft skills, Digital design.

1 INTRODUCTION

The exponential growth in information and communication industry has resulted in technological explosion. Engineering graduates have to switch their technical interests multiple times during the entire career. Consequently, engineering graduates should be highly adaptable to satisfy the needs of industry [1]. However, there is a gap between the expertise developed during the engineering education and the expertise required for engineering work [2] – [4].

The pure lecture-based teaching methodologies are not addressing the issue of competencies gap in an effective way. To solve the issue of competencies gap, problem-based learning is emerging as an attractive solution [6] – [14]. While the problem-based learning has shown some significant benefits, there are certain limitations: (i) students face difficulty in starting their projects without the cohesive vision of course contents, (ii) the problem is suggested by the instructor and students do not go through the identification and formulation phase, (iii) students cannot perform an in-depth study without acquiring the essential knowledge.

This article proposes a teaching methodology to develop the desired competencies in the engineering graduates by taking the Digital System Design course in Computer Engineering (CpE) domain as a case study.

However, the proposed methodology in this article can be applied to other courses in multiple engineering disciplines. The main characteristics of the proposed methodology are:

- Coherent vision of the course contents
- Systematic delivery of the laboratory practicals
- Development of technical and soft skills through problem-based learning

The evaluation of proposed methodology is performed through the analysis of quantitative data for SOs Assessment/evaluation results show a significant improvement in achievement of SOs.

2 RELATED WORK

The related work is divided into two categories: (1) Coherent vision of the contents and (2) Problem-based learning.

2.1 State-of-the-art in Coherent Vision:

The initial guidelines for coherent vision of the contents were proposed under the umbrella of “integrated learning” in [15] and [16]. These guidelines do not provide the implementation of integrated learning. The features of integrated learning were implemented for Electrical and Computer Engineering program in [17]. However, different courses were integrated without any cohesiveness.

The work in [18] provided cohesiveness among multiple courses by using forward and backward references. Relationships among different courses were highlighted by utilizing previous designs as components in subsequent courses. However, the approach did not consider the coherent development of design skills obtained in the laboratory sessions.

The methodology for continuous development of engineering students’ design skills was presented in [19]. The methodology started by providing the structured design experience, went through the guided design experience, and finally culminated in an open-ended design experience. The approaches of [20] and [21] were also based on integrated laboratory experiments seamlessly integrated into all levels of the digital design courses.

2.2 Review of Problem-based Learning Techniques in Engineering Education:

Problem-based learning (PBL) is a non-conventional approach that stresses the introduction of real-life problem. The use of PBL, where students focus on problem-solving skills rather than factual technical knowledge, is increasing because of its suitability to prepare future engineers [6] – [14].

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A project-based course related to telecommunications engineering was proposed in [6]. The course was flexible based on industry requirements, program requirements and level of guidance provided to the students.

The project work presented in [7] covered the programmable, configurable and dedicated processors, memory technology, peripherals, and the design and implementation of complete embedded systems. Image processing application was used to illustrate the concepts.

Similarly, [8] described a project-based course on hardware/software (HW/SW) co-design for basic public key (RSA) application. HW/SW co-design is emerging as a system level design methodology in the CpE discipline. The course proposed a step-wise approach with assignments that build on each other. Students were required to make their own decisions at different steps of the project.

An active learning environment, where the main focus is the involvement of students, was proposed in [12], [13] and [14] to provide industry relevant skills. First, the laboratory classes/sessions provided guided experimentation and then students worked in teams on multiple projects selected by the instructor. Guided experimentation was provided through some well-defined tutorials, exercises, manipulation of laboratory equipment and related activities.

3 PROPOSED METHODOLOGY

In order to address the competency gap, an integrated teaching methodology is proposed. It integrates the contents-based learning with problem-based learning. Contents-based learning consists of coherent development of course contents Problem-based learning involves the development of technical as well as soft skills. In the following sub-sections, the proposed methodology is illustrated by taking the case study of Digital System Design course.

3.1 Coherent vision of the course contents

The coherent vision of Digital System Design (DSD) is based on: (1) System model for the Computer Engineering(CpE) core courses, (2) Coherent vision of the DSD contents.

3.1.1 System model for the CpE core courses:

The system model for the CpE core courses, shown in Fig. 1, begins with courses in circuit design and programming, and progresses through a sequence of system-level courses. Students are exposed to CpE core concepts that build upon one another and finally culminate in a senior-level capstone design experience.

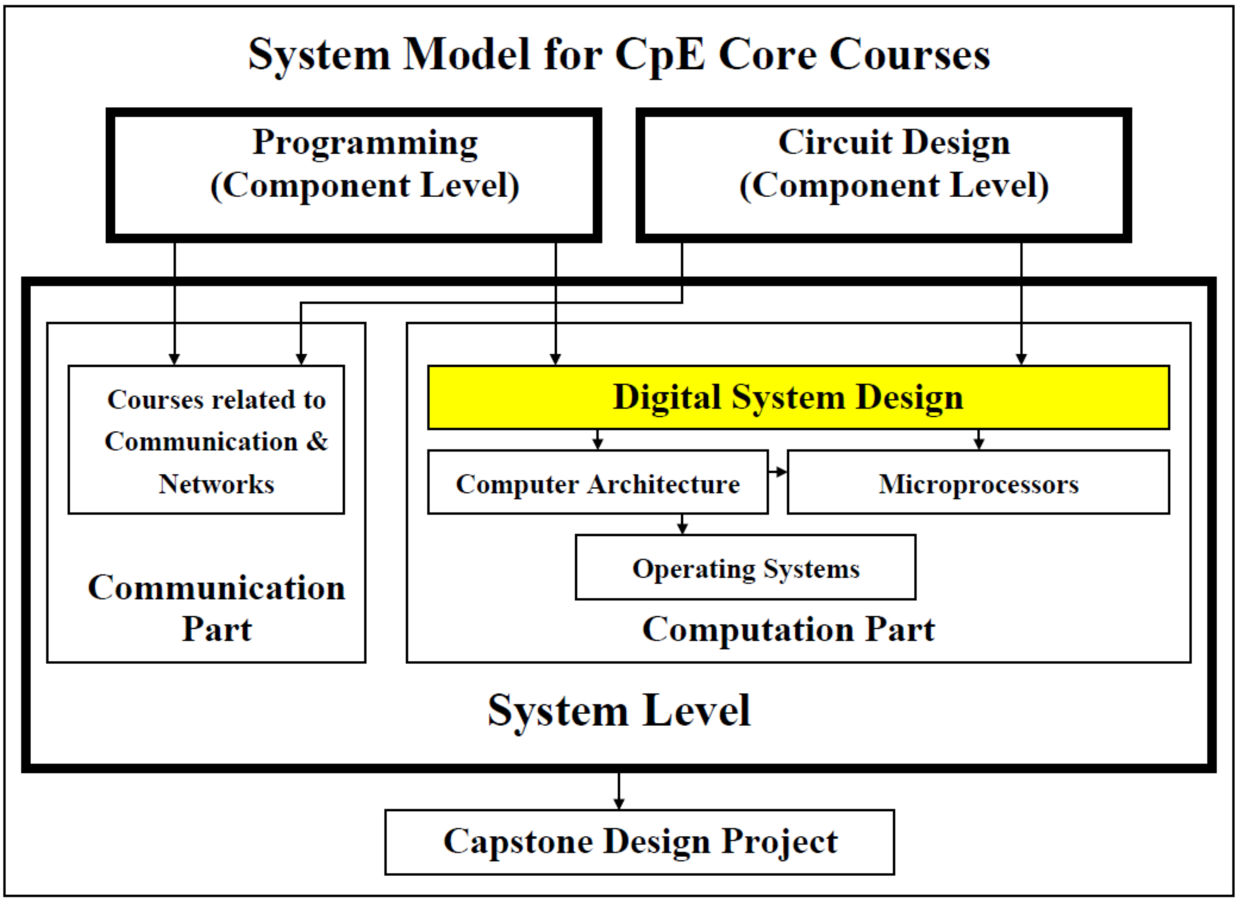

Fig. 1.System model to highlight the coherent vision of CpE core courses

Courses related to circuit design and programming are termed as component-level courses, because there is no integration of hardware and software in these courses. Onthe other hand, system-level courses provide an integration of hardware and software. System level courses are further divided into computation and communication parts.

The case study in this article, Digital System Design, is related to the computation part as shown in Fig. 1. This is the point at which the two elements, hardware and software, combine. Forward and backward references to other courses in the curriculum are used to help students tie concepts together.

3.1.2 Holistic view of the Digital System Design:

The holistic view of the Digital System Design course, shown in Fig. 2, illustrates that the contents are divided into specification and implementation parts. Systems are specified behaviorally or structurally in an hardware description language (HDL). Similarly, systems are implemented either by using fixed logic (for example, ASICs) or programmable logic (for example, FPGAs).

Behavioral description can be described in two different ways: combinational or sequential. In case of combinational behavior, truth tables are generally used. On the other hand, sequential behavior can be described either by Finite State Machines (FSMs) or High Level State Machines (HLSMs)depending upon the abstraction level.

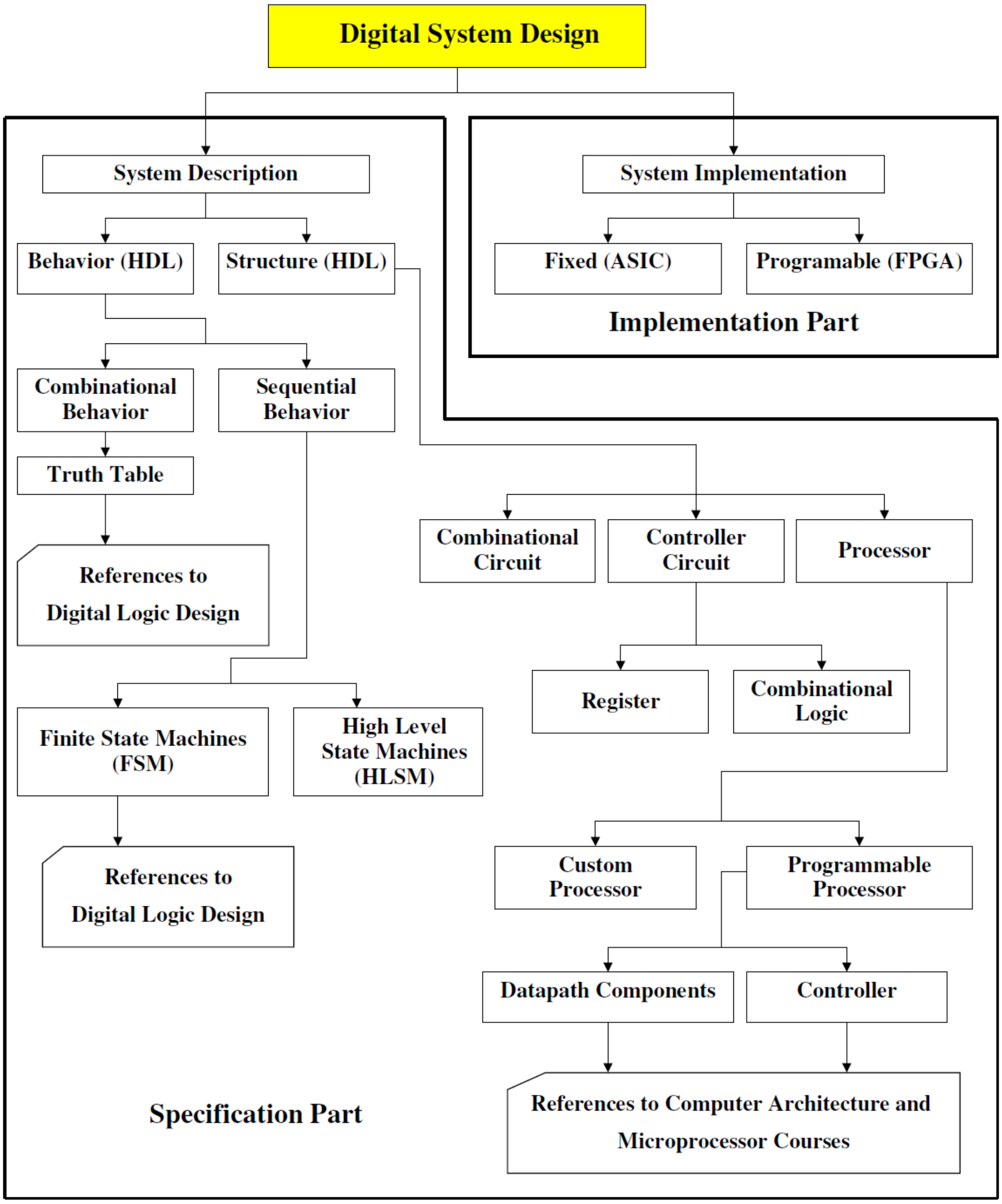

Fig. 2.Holistic view of Digital System Design contents

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Structural descriptions are derived from behavioral descriptions. Combinational logic (consisting of logic gates) is used for pure combinational behavior. Sequential behavior with FSMs is structurally described with controller that in turns consists of a Register and combinational logic.

Sequential behavior with HLSMs at Register Transfer Level (RTL) are structurally described with processor, that in turns consists of multiple data path components (for example, comparator, multiplexor, adder etc) and controller. Finally, two different types of processors are custom and programmable.

3.2 Systematic Laboratory Practical's

This Section will describe the systematic laboratory practical's (second part of the contents-based learning). In other words, the technical knowledge is taught in lectures (theory classes)and the technical skills are taught in the laboratory classes, divided into three categories: Procedure-Based (PB), Semi-Independent (SI) and Completely-Independent (CI). The listof laboratory experiments is listed in Table I.

3.2.1 Procedure-based:

Table I shows that the first five weeks of laboratory activities are procedure-based. During this period, students get enough practice for simulation and synthesis of combinational as well as sequential circuits. The main objective of procedure-based design experience is to bring students' attention to the concept and practice of using engineering tools for simulation and synthesis of digital systems. The case study in this article used ISE design environment and Xilinx FPGA boards.

TABLE I

LABORATORY PRACTICALS FOR SYSTEMATIC DESIGN SKILLS:PB=PROCEDURE-BASED, SI=SEMI-INDEPENDENT,CI=COMPLETELY-INDEPENDENT

Weeks	Title of experiment	Type
1.	Introduction to simulation environment (ISE design tools) and FPGA prototyping boards from Xilinx	PB
2.	Simulation and synthesis of combinational behavior	PB
3.	Structural modeling of combinational circuits	PB
4.	Simulation and synthesis of sequential behavior	PB
5.	Structural modeling of sequential circuits (controller)	PB
6.	Design of combinational data path components	SI
7.	Design of sequential data path components	SI
8.	Register Transfer Level (RTL) modeling	SI
9.	Custom processor designing by modeling data pathcomponents and controller	SI
10.	Problem-based learning	CI

3.2.2 Semi-independent:

Table I shows that the weeks 6 - 9 of laboratory activities are semi-independent. During this period, students first design the data path components and controller, and then merge them in the form of a processor at RTL. The main objective of semi-independent design experiences to start students exercising digital design by themselves. Students' confidence is built by making them autonomous. They achieve the assigned tasks with the little guidance from the lab instructor. The intention is to prepare the students for problem-based learning.

3.2.3 Completely-independent:

Procedure-based and semi-independent activities in the laboratory finally culminate into completely-independent activities. Table I shows that the last five weeks (10 - 14) of laboratory activities are completely independent. This stage is actually the problem-learning phase of the proposed methodology, where students identify, formulate and solve an engineering problem related to the contents of the course. The main objective of this stage is to make students completely independent in taking all the design process decisions by themselves, with almost no guidance.

3.3 Problem-based Learning

This section will describe the various facets of problem-based learning. In this phase, students work in the form of different teams. They use hardware description language (Verilog in this case study) to simulate and synthesize their designs. However, coherent delivery of the contents enables the students to identify various alternate solutions of the same design problem. Typical examples are microprocessor-based solution (Microprocessor course) and circuit design using fixed logic ICs (Digital Logic Design course).

To summarize, the main steps are:

- Preparation of a proposal
- Suggestions for alternate solutions to the problem
- Design and implementation
- Technical report writing and oral presentation.

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4 ASSESSMENT OF PROPOSED METHODOLOGY

The assessment of proposed methodology was carried out through analysis of quantitative data, collected by assessing the SOs through written exams, technical reports and presentations. The analysis of quantitative data is organized into two different forms: (1) ABET self-study and(2) Determination of comprehension level. The proposed methodology was introduced in spring 2014.The results of proposed methodology were compared with the previous data (Fall 2013), termed as base study.

4.1 ABET Self-Study

ABET self-study results for the Digital System Design course are given in Table II.

TABLE II

ABET SELF-STUDY RESULTS

SOs	Base Study		Proposed Methodology	
	M (%)	P (%)	M (%)	P (%)
a.	33.3	47	25	58
b.	8.3	48	12.5	65
c.	45	54	25	58
d.	NA	NA	3.8	53
e.	NA	NA	5	59
f.	NA	NA	3.8	53
g.	NA	NA	3.8	53
h.	NA	NA	NA	NA
i.	NA	NA	3.8	53
j.	NA	NA	NA	NA
k.	8.3	48	12.5	65

The first column in Table II lists the SOs while the remaining columns display assessment results for the SOs (a to k).Assessment results are shown for two different semesters: (1)The data in second and third columns, termed as base study, was collected in Fall 2013 where the proposed methodology was not introduced. (2) The data in fourth and fifth columns was collected in Spring 2014, where the proposed methodology was introduced.

Data in each semester is further divided into two columns. For example, the SO ‘a’ has two columns, M(a) and P(a). M(a)is the marks that were allocated to questions used in the assessment of SO ‘a’. P(a) is the percentage of students who achieved 70% or higher marks in SO ‘a’.

4.2 Determination of Comprehension Level

ABET self-study did not provide any information about the comprehension level of students in each SO. Consequently, this section provides the average comprehension level in each SO.

Generally speaking, the students’ scores in the examination reflect their degree of comprehension of the knowledge. Therefore, the Average Comprehension Level (ACL) for each SO is the weighted average of the degree of comprehension for the relevant questions in the exam, as shown in Equation 1.

$$ACL = \frac{\sum_{j=1}^{n} M_{sj} * DC_{sj}}{\sum_{j=1}^{n} M_{sj}} \qquad (1)$$

Where:

- ‘s’ is the SO
- ‘n’ is the number of questions for SO ‘s’
- ‘Msj ’ is the maximum score of question ‘j’
- ‘DCsj ’ is the degree of comprehension for question ‘j’ derived from the students’ answers to question ‘j’.

$$DC_{sj} = \frac{\frac{1}{m}\sum_{k=1}^{m} S_{sjk}}{M_{sj}} \qquad (2)$$

Where ‘m’ is the number of students, and ‘Ssjk’ is the score of student ‘k’ on the question ‘j’ of SO ‘s’. For example, SO ‘a’ is assessed in the examination, through three questions, with maximum scores of 5, 5, and 10 respectively. The DC of the first question is computed by dividing the average score of this question (i.e. 3.25) with the maximum score (i.e. 5), as shown in Equation 3.

$$\begin{aligned} DC_{Q1} &= \left(\frac{3.25}{5}\right) * 100\% \\ &= 65\% \end{aligned} \qquad (3)$$

Similarly, the DC for the second and third questions are computed such that the corresponding DC of the three questions is 65%, 63.5% and 60.5%, respectively. Consequently, the ACL for the SO ‘a’ is computed by using the corresponding DC of the three questions (65%, 63.5% and 60.5%), as shown in Equation 4.

$$\begin{aligned} ACL_a &= \frac{5 * 65\% + 5 * 63.5\% + 10 * 60.5\%}{5 + 5 + 10} \\ &= 62.4\% \end{aligned} \qquad (4)$$

Table III presents the ACL for all the SOs. The values of ACL for outcomes ‘a’, ‘b’, ‘c’, and ‘k’in the base study were 47.9, 48.5, 54.2 and 48.3 respectively. After applying the proposed methodology presented in this article, the average comprehension levels for these outcomes have improved to 62.4,63.1, 65.3 and 68.4 respectively, showing the viability of the proposed methodology. Furthermore, the base methodology (executed in Fall 2013)did not address many SOs (shown as NA) such as 'd', 'e','f', 'g', 'i'.

TABLE III

PERCENTAGE OF AVERAGE COMPREHENSION LEVEL FOR EACH SO.

SOs	Base Study	Proposed Methodology
a.	47.9	62.4
b.	48.5	63.1
c.	54.2	65.3
d.	NA	69.8
e.	NA	66.4
f.	NA	68.5
g.	NA	60.3
h.	NA	NA
i.	NA	60.8
j.	NA	NA
k.	48.3	68.4

5 CONCLUSION

This article presented an integrated methodology for the development of competencies required by industry. Digital System Design course was taken as a case study. The proposed methodology started with the coherent delivery of course contents (Digital System Design in this article) and the systematic laboratory practical's. The coherent delivery of course contents based on the system model of entire curriculum (Computer Engineering in this article) whiles the systematic delivery of laboratory practical's was organized into different phases. Then, during the problem-based learning, students worked in multiple teams to identify and solve a problem relevant to the core contents. Finally, the proposed methodology was assessed through analysis of quantitative data.

REFERENCES

1. Carol Arlett, Fiona Lamb, Richard Dales, Liz Willis, and EmmaHurdle, "Meeting the needs of industry: the drivers for change in engineering education", In Engineering Education, vol. 5, no. 2, pp.18–25, 2010.
2. Mohamed Ashraf, Abdullah Alsadaawi, Mohamed Elmadany, SaeedAl-Zahrani and AbdelhamidAjbar, "Identification of Top CompetenciesRequired from Engineering Graduates: A Case Study of SaudiArabia", In International Journal of Engineering Education, vol. 29,no. 4, pp. 967–973, 2013
3. ABET Criteria for Accrediting Engineering Programs,http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3139
4. European Network for Accreditation of Engineering Education,http://www.enaee.eu/
5. Honor J. Passow, "Which ABET competencies do engineering graduates find most important in their work?", In Journal of Engineering Education, vol. 101, no. 1, pp. 95–118, 2012.
6. HadiAliakbarian et al. "Implementation of a Project-Based Telecommunications Engineering Design Course", In IEEE Transactions on Education, vol. 57, no. 1, pp. 25–33, 2014.
7. Leonel Sousa, Samuel Antao, and Jos Germano, "A Lab Project on the Design and Implementation of Programmable and Configurable Embedded Systems" In IEEE Transactions on Education, vol. 56, no.3, pp. 322–328, 2013.
8. Leif Uhsadel et al, "Teaching HW/SW Co-Design With a Public Key Cryptography Application" In IEEE Transactions on Education, vol.56, no. 4, pp. 478–483, 2013.
9. O.B. Adamo, P. Guturu, M.R. Varanasi, "An innovative method of teaching digital system design in an undergraduate electrical and computer engineering curriculum", In IEEE International Conference on Microelectronic Systems Education, 2009.
10. Antonio J. Araujo and Jose C. Alves, "A project based methodology to teach a course on advanced digital systems design", In WSEASTransactions on Advances in Engineering Education, vol. 5, no.6, pp.437–446, 2008
11. Christopher M. Kellett, "A project-based learning approach to programmable logic design and computer architecture", In IEEE Transactionson Education, vol. 55, no. 3, pp. 378–383, 2012.
12. Ming-Der Jean, " Integration of a Project-Based Learning Strategy with Laboratory Activity: A Case Study of a Nanotechnology Exploration Project", In International Journal of Engineering Education, vol. 30,no. 1, pp. 240–253, 2014.
13. AmanYadav, DipendraSubediPsychometrician, Mary A. Lundebergand Charles F. Bunting, "Problem-based Learning: Influence on Students 'Learning in an Electrical Engineering Course", In Journal of Engineering Education, vol. 100, no. 2, pp. 253–280, 2011.
14. ArjunaMadanayake et al, "Teaching freshmen VHDL-based digital design", In IEEE International Symposium on Circuits and Systems(ISCAS), pp. 2701–2704, 2012.
15. James D. Mccowan and Christopher K. Knapper, "An Integrated andComprehensive Approach to Engineering Curricula, Part One: Objectives and General Approach", In International Journal of Engineering Education, vol. 18, no. 6, pp. 633–637, 2002.
16. Daniel J. Moore and David R. Voltmer, "Curriculum for an Engineering Renaissance", In IEEE Transactions on Education, vol. 46, no. 4,pp.452–455, 2003.
17. Sung C. Hu, "A Wholesome ECE Education", In IEEE Transaction son Education, vol. 46, no. 4, pp. 44–451, 2003.
18. Kenneth G. Ricks, David Jeff Jackson and William A. Stapleton, "An Embedded Systems Curriculum Based on the IEEE/ACM Model Curriculum", In IEEE Transactions on Education, vol. 51, no. 2, pp.262–270, 2008.
19. Habib-ur-Rehman and Yousef Al-assaf, "An Integrated Approach for Strategic Development of Engineering Curricula: Focus on Students 'Design Skills", In IEEE Transactions on Education, vol. 52, no. 4, pp.470–481, 2008.
20. Ying Tang, Linda M. Head, Ravi P. Ramachandran, and Lawrence M.Chatman, "Vertical integration of system-on-chip concepts in the digital design curriculum", In IEEE Transactions on Education, vol. 54, no.2, pp. 188–196, 2011.
21. Douglas W. Stamps, "A Vertically Integrated Design Sequence", InIEEE Transactions on Education, vol. 29, no. 6, pp. 1580–1590, 2013.
22. Lei Jing, Zixue Cheng, Junbo Wang and Yinghui Zhou, "A Spiral Step-by-Step Educational Method for Cultivating Competent Embedded System Engineers to Meet Industry Demands", In IEEE Transactionson Education, vol. 54, no. 3, pp. 356–365, 2011.
23. Muhammad Rashid and Imran A. Tasadduq, "Holistic Development of Computer Engineering Curricula Using Y-Chart Methodology", Invitee Transactions on Education, Date of publication. 24th February2014.