Competency-Based Calisthenics of Learning Outcomes for Engineering Education

D. Asir Antony Gnana Singh and E. Jebamalar Leavline

Anna University Chennai, BIT Campus, Tiruchirappalli – 24, India
asirantony@gmail.com, jebi.lee@gmail.com

Abstract

Today the number of students pursuing education in various engineering disciplines is on the rise. With the growing demand for higher achievements of learners, engineering institutions are expected to develop and implement a competence-based curriculum. Hence designing curriculum and courses in engineering education with stress on learning outcomes is the goal. This paper presents a practical approach to perception of teaching-learning process in engineering education, systems model of human behavior and design of curriculum based on learning outcomes.

Keywords: *Action verb, Bloom's taxonomy, Cognitive domain, Engineering, Engineering Education, Human behavior, Learning outcomes, Learning, Teaching, Technical education*

1. Introduction

Rapid developments in the fields of engineering and technology were the result of enduring researches and professional practices all over the world. Therefore, many nations have a focus on improving the quality of engineering and technical education [1]. Scores of institutions offering engineering education have emerged across the globe. Yet, especially in developing nations, there are frequent complaints from the employers and corporations about the skill set and the analytical ability of engineering graduates, which questions the success of engineering education institutions in the recent past.

There are a number of factors which can affect the quality of engineering education such as specifying clear educational goals, educational methods adopted, assessment methods, the balance between 'content' and 'process' in the educational programs, overloaded curriculum, the use of information technology, and the modern methods of quality assurance. According to John J. Sparkes [2], the foremost factor to be considered is 'specifying clear educational goals'. This includes setting up and mapping learning objectives and outcomes with competence based curriculum towards the educational goals.

Hence, setting of curriculum based on learning outcomes, has been a prime aspect for the success of any engineering educational institution. In the following sections, we describe the teaching-learning process in engineering education, the systems model of human behavior, the design of curriculum based on learning outcomes and the benefits of learning outcomes based approach for quality engineering education.

2. Problem Definition

The two key elements of teaching faculty—proficiency in the discipline and teaching methodology—focus on moulding the behaviour of students through the teaching-learning process. The goals of engineering education, thus, cannot be accomplished if any of these elements fail. Although the teaching faculties are expected to possess higher levels of proficiency in their respective disciplines, many of them allegedly approach this profession with poor insight into the teaching methodology, since most of them take up teaching soon after completion of their master/doctoral degree in any engineering discipline [3]. Lack of teaching methodology shall degrade the learning system in engineering education. The robustness of the teaching methodology, however, mainly relies on a curriculum built upon learning outcomes.

Under these circumstances, we present a practical way of designing a curriculum based on learning outcomes (See Appendix) and teaching methodology to take up the quality of engineering education to great heights. It is believed that this paper will be of immense use to the young teaching professionals as well as educational practitioners [4].

3. Teaching Learning Process in Engineering Education

Engineering education combines theoretical and practical approaches in teaching-learning process [5]. Teaching and learning (Figure 1) is a continuous process [6]. Learning imparts eternal transformation in learner behaviors as a result of observance, experience or practice. Teaching is the purposeful direction and management of the learning process [7].

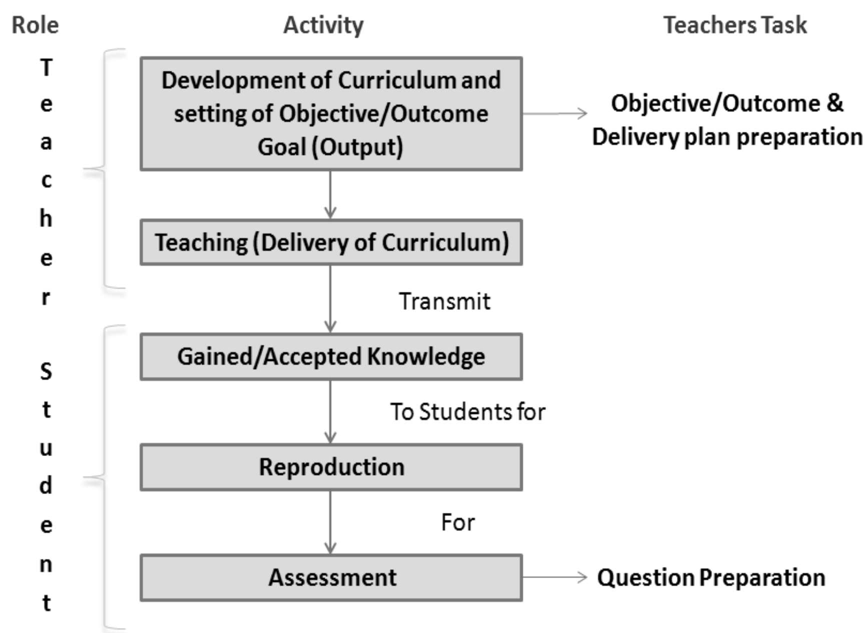

Figure 1. Teaching-learning process

The teaching-learning process is defined by five phases. The first is “development phase”. In this phase, the teacher or the institution develops the curriculum, syllabus and courses with objectives, aims and expected outcomes [8]. The second is “delivery phase”. Here the instructor delivers the knowledge to the learner through various teaching aids. The third is “acceptance phase”. In this phase, the learner acknowledges for receiving the knowledge. The fourth is “reproduction phase”. In this phase, the learner is expected to reproduce or interpret the gained knowledge through various actions or activities. The fifth is “assessment phase”. In this phase, the learner is examined through various appraisal methods to evaluate how far the learner has gained the knowledge.

3. Systems Model of Human Behavior

The human being is perceived as a union of body (physical body) and mind (brain/soul/spirit/heart). Body comprises three components: genetics, physiological structure, and functioning and overt behavior. In the same way, mind is composed of three components: cognition (thinking), affection (emotion, feeling, attitude) and psychomotor (acting, doing) (Figure 2). Psychomotor means "...of or relating to movement or muscular activity associated with mental processes [4].

The systems model of human behavior in engineering education is illustrated in Figure 3. The input of the model is teaching and delivering knowledge of engineering modules to a student; the output is behavior changes in the student in terms of a practicing engineer [9].

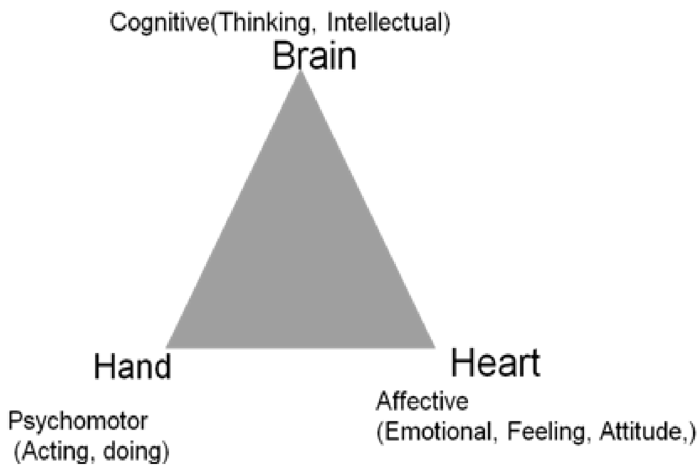

Figure 2. Human Behaviour Model

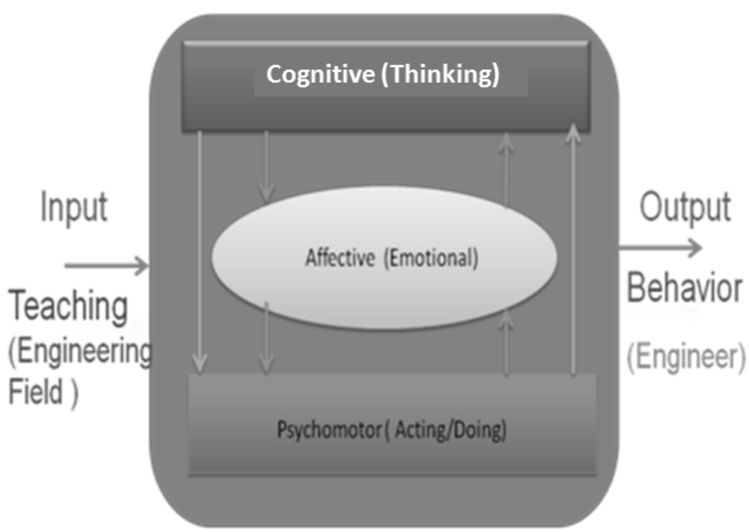

Figure 3. Systems Model of Human Behaviour in Engineering Education

4. Learning Outcomes

Learning outcomes are statements of what a student is expected to know, understand and/or be able to demonstrate after successful completion of a process of learning [10]. The learning outcomes fall into four distinct levels, such as “Programme”, “Principal”, “Enabling” and “Sub-enabling”. The “programme” outcome is an abstract, high-level objective of what the learner should be able to do/demonstrate after completion of a degree/diploma programme [11, 12]. The “principal” outcome is used to indicate what the learner should be able to do/demonstrate after completion a particular module. The “enabling” outcome is used to indicate what the learner should be able to do/demonstrate after completion of a particular unit. The “sub-enabling” outcome, and its related tasks, is used to indicate what the learner will be able to do/demonstrate after completion of a particular subtopic within a unit [13].

4.1. Aims, Objectives and Learning Outcomes

Aims are broad purposes or goals, while objectives are specific steps to reach the goals [12]. Objectives are intentions of the instructor in measurable terms. Learning outcomes are what is expected out of a learning process. They are specific, measurable achievements stated as those of the student [8]. Learning outcomes should specify the minimum acceptable standards for a student to be able to pass a module or course (threshold level). Clearly stated, learning outcomes are what teachers want students to achieve.

4.2. Purposes of Learning Outcomes

It is often the case that aims and objectives are written in a way that places emphasis on teaching [14]. However, learning outcomes should place emphasis on the learner by: making it clear to students what is expected of them and making it clear to teachers what students are expected to learn in the programs/modules; eliminating the need to assess student knowledge and skills at the start of a programme/module; helping teachers to select the most appropriate teaching strategy for the intended learning outcomes, *e.g.*, lecture, seminar, tutorial, group work, discussion, student presentation and laboratory work, *etc.*; and finally helping teachers to select the most appropriate tools to assess the achievement of learning outcomes, *e.g.*, project, essay, multiple choice questions, end of term examination, *etc.*

4.3 Preparation of Learning Outcomes

According to the Bloom’s taxonomy [15], teachers should design lessons and tasks to help students to meet stated objectives. Bloom identified three domains of learning—cognitive, affective and psychomotor, with an ascending order of complexity. In a most advanced work in the cognitive domain, he drew up a classification (or taxonomy) of thinking behaviors from the simple recall of facts up to the process of analysis and evaluation. Bloom proposed that cognitive or knowing domain is composed of six successive levels, arranged in a hierarchy as shown in Figure 4.

4.3.1. Formula of learning outcomes: Learning outcomes are the combination [16] of action verbs taken from Bloom’s taxonomy and what students are expected to know after completion of the programme/course. The formula shown in Figure 5 can be used to prepare the learning outcomes [17].

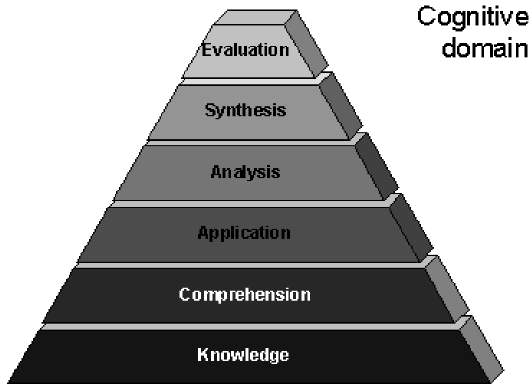

Figure 4. Hierarchy of Cognitive Domain

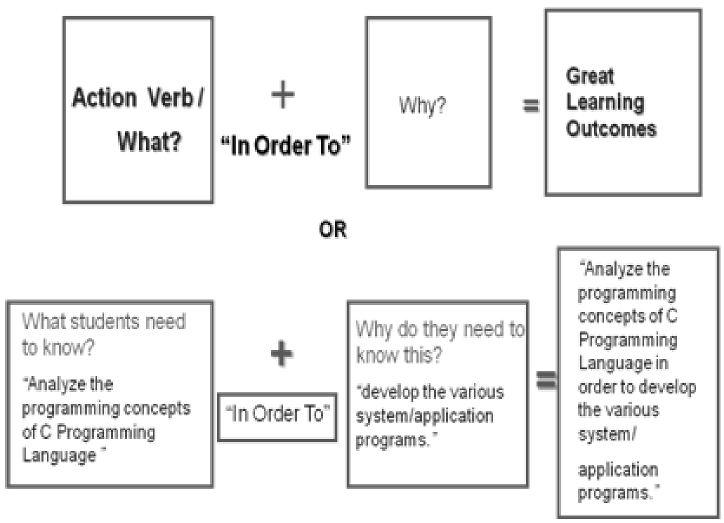

Figure 5. Formula of Learning Outcomes

4.4. Learning Outcomes in Cognitive Domain

Learning outcomes are usually written based on Bloom's taxonomy [9] which provides an excellent structure and a variety of action verbs to write the learning outcomes and construct questionnaires according the level of thinking. In the following section, we describe the various levels of learning outcomes based on Bloom's taxonomy [12, 15, 16].

4.4.1Knowledge: The first level of thinking is knowledge. In this level, the learner may have the ability to recall or remember facts without understanding them. This level is assessed by various action verbs such as [15,18] "define", "describe", "identify", "label", "list", "match", "name", "outline", "reproduce", "select" and "state". Consider the following examples of knowledge-based questions.

- List the various languages supported by.NET framework.
- Name the layers of wireless application protocol.
- Define control hazard.

- Label the parts of the 8085 microprocessor architecture.
- Outline cellular system.

4.4.2 Comprehension: The second level of thinking is comprehension. In this level, the learner may have the ability to understand and interpret learned information. This level is assessed by various action verbs as follows: “convert”, “defend”, “distinguish”, “estimate”, “explain”, “extend”, “generalize”, “give example”, “infer”, “paraphrase”, “predict”, “rewrite” and “summarize”. Consider the following examples of comprehension-based questions:

- Classify distributed memory machines based on communication models.
- Distinguish indirect addressing and register indirect addressing mode.
- Explain instruction-level parallelism with a suitable example.
- Identify the techniques for improving cache performance.
- Paraphrase the implementation method of Tomasulo’s approach.

4.4.3 Application: The third level of thinking is application [15]. In this level, the learner may have the ability to use learned material in new situations, e.g. use the ideas and concepts to solve problems. This level is assessed by various action verbs as follows: “apply”, “change”, “compute”, “demonstrate”, “discover”, “manipulate”, “modify”, “operate”, “predict”, “prepare”, “produce”, “relate”, “show”, “solve” and “use”. Consider the following examples of application-based questions.

- Apply the discrete cosine transform for image compression technique.
- Show a timeline diagram for the sliding window algorithm.
- Relate packet switching and virtual circuit.
- Compute the propagation delay of a 20-km-long point-to-point fiber link when the speed of light is 2×108 m/s in the fiber.
- Predict the formulas of ionic compounds formed by the following elements.

4.4.4 Analysis: The fourth level of thinking is analysis Ibid.. In this level, the learner may have the ability to break down information into its components, e.g. look for inter-relationships. This level is assessed by various action verbs as follows: “breakdown”, “diagram”, “differentiate”, “discriminate”, “distinguish”, “identify”, “illustrate”, “infer”, “outline”, “point out”, “relate”, “select”, “separate” and “subdivide”. Consider the following examples of analytical questions.

- If a two-way handshake is done instead of a three-way one, is there possibility of deadlock?
- Break down the socket connection set up.
- Discriminate the dynamic host configuration protocol (DHCP) and simple network management protocol (SNMP).
- Diagram a flowchart to illustrate the logic of Sutherland-Hodgeman algorithm.
- Illustrate the ATM reference models

4.4.5 Synthesis: The fifth level of thinking is synthesis. In this level, the learner may have the ability to put parts together. This level is assessed by action verbs as follows: “categorize”, “combine”, “compile”, “compose”, “create”, “devise”, “design”, “explain”, “generate”, “modify”, “organize”, “plan”, “rearrange”, “reconstruct”, “relate”, “reorganize”, “revise”, “rewrite”, “summarize”, “tell” and “write”. Consider the following examples of synthesis-based questions.

- Categorize the various types of operating systems based on their application.
- Combine the characteristics of wrapper and filter method algorithms to get optimal solution for feature selection in data mining.
- Compose a scan-line algorithm for the removal of hidden lines from a scene of 3D graphics display.
- Relate the pseudo code for Weiler-Atherton algorithm and A-buffer visible surface algorithm.
- Organize a workshop on recent trends in mobile computing.

4.4.6 Evaluation: The fifth level of thinking is evaluation Ibid.. In this level, the learner may have the ability to judge the value of a material for a given purpose. This level is assessed by some of the action verbs as follows: “appraise”, “compare”, “conclude”, “contrast”, “criticize”, “describe”, “discriminate”, “explain”, “justify”, “interpret”, “relate”, “summarize” and “support”. Consider the following examples of evaluation-based questions.

- Assess the important factors for improvement of productivity of a car production unit in the year of 2013.
- Summarize the involvement of Charles Babbage who originated the concept of programmable computers in the field of mathematics and philosophy.
- Appraise the performance of the employees of a manufacturing company.
- Justify how a particular project was awarded among all other projects.
- Interpret the pseudo code in to a high-level language executable program.

4.5 Benefits of the Learning Outcomes Approach

The learning outcomes approach to teaching and learning is receiving wider support. D. Kennedy [12, 19] asserts that learning outcomes:

- Help teachers to tell students more precisely what is expected of them;
- Help students to learn more effectively: students know where they stand and the curriculum is made more open to them;
- Help teachers to design materials more effectively;
- Make students clear what they can hope to gain from a particular course or lecture;
- Help teachers select appropriate teaching strategy matched to the intended learning outcome, *e.g.*, lecture, seminar, group work, tutorial, discussion, peer group presentation or laboratory work;
- Help teachers explain more precisely what a particular activity is expected to achieve;

- Assist in setting questions for examinations based on materials delivered;
- Ensure that appropriate teaching and assessment strategies are employed.

5. Conclusions

This paper presented the teaching learning process for the engineering education, systems model of human behavior with an insight on learning outcomes and its importance.The robustness of the teaching methodology mainly relies on a competency based curriculum built upon learning outcomes. A road map for designing the learning outcomes and setting the question papers is presented. This will encourage the young engineering faculty to improve the quality of engineering education so that they can produce excellent engineers for the welfare of the society.

References

[1] P. Black and D. Wiliam, "Inside the black box: Raising standards through classroom assessment", Granada Learning, **(2006)**.
[2] J. J. Sparkes, Int. J. of Continuing Engineering Education and Life-Long Learning, vol. 1, no. 1, **(1990)**.
[3] S. Bergan, "Recognition issues in the Bologna Process", Council of Europe, **(2003)**.
[4] R. J. Armstrong, "Developing and Writing Behavioral Objectives", Educational Innovators Press, Arizona, **(1970)**.
[5] J. Biggs, "Aligning teaching and assessing to course objectives", Proceedings of Teaching and Learning in Higher Education: New Trends and Innovations, **(2003)** April 13-17; Portugal.
[6] G. O'Neill, S. Moore and B. McMullin, (Eds.), "Emerging issues in the practice of University Learning and Teaching", http://www.aishe.org/readings/2005-1/.
[7] J. Biggs and C. Tang, "Teaching for quality learning at university", Open University press, **(2011)**.
[8] S. Brown and A. Glasner, "Assessment Matters in Higher Education: Choosing and Using Diverse Approaches", ERIC, **(1999)**.
[9] Brüssel, "ECTS Users Guide", **(2005)**.
[10] Writing Learning Outcomes, Canada: Learning Resources Unit, British Columbia Institute of Technology, **(1996)**.
[11] J. Kohler, L. Purser and L. Wilson, "EUA Bologna Handbook: Making Bologna Work", vol. 4, **(2006)**.
[12] D. Kennedy, Á. Hyland and N. Ryan, "Writing and using learning outcomes: A practical guide", University College Cork, **(2007)**.
[13] J. Allan, Studies in Higher Education, vol. 21, no. 1, **(1996)**.
[14] S. Brown and P. Knight, "Assessing Learners in Higher Education", Teaching and Learning in Higher Education Series, ERIC, **(1994)**.
[15] B. S. Bloom, M. D. Engelhart, E. J. Furst, W. H. Hill and D. R. Krathwohl, "Taxonomy of educational objectives: Handbook I: Cognitive domain", New York: David McKay, vol. 19, **(1956)**, pp. 56.
[16] W. R. Dawson, "Extensions to Bloom's Taxonomy of Educational Objectives", Putney Publishing, **(1998)**.
[17] R. F. Mager, "Preparing instructional objectives", Primedia E-launch LLC, **(2012)**.
[18] D. R. Krathwohl, "Theory into practice", vol. 41, no. 4, **(2002)**.
[19] NCGIA GISCC Learning Outcomes, http://ncgia.ucsb.edu/giscc/units/format/outcomes.html.

Appendix:

Writing Learning Outcomes for a Module

We demonstrate the writing of learning outcomes for a module CSE-XXXX: Operating System. The main constrain is to choose action verbs from higher, medium and lower domain for principal outcome, enabling outcomes and sub enabling outcomes respectively.The main constrain is to choose the action verb from higher domain to lower domain for principal outcome to sub enabling outcomes. If the teacher knows very well about the outcomes then only the teacher can teach according the depth of the core concepts of the course.

CSE-XXXX: OPERATING SYSTEM

UNIT I INTRODUCTION

Mainframe systems –Desktop systems – Multiprocessor systems Distributed systems – Clustered systems – time systems – Hardware Protection Systems Components – Handheld systems – Operating System services – System Calls – system Programs – System Structure – Visual Machines

Table 1. Learning outcomes for the above module, being classified as principal, enabling and sub-enabling outcomes, are presented in the below table

Principal/Course/Module Outcome		Enabling Outcomes		Sub-enabling Outcomes	
1.0	Analyze the concepts of Operating System related to the Process Management, Process Coordination, Memory management and Storage management in order to Improve the Performance of the System	1.1	Describe the basic concepts of Operating system	1.1.1	Name the various types of computer organization
				1.1.2	Define Hardware protection Components
				1.1.3	List out the types of System Calls
				1.1.4	Define System Program
				1.1.5	Outline the Visual Machines
		1.2	Recognize the concepts of Process Management	1.2.1	Summarize the process concepts and threads
				1.2.2	Use the Principles of Process Synchronization.
				1.2.3	Describe the Deadlock Characterization
				1.2.4	List the Methods for handling Deadlocks
				1.2.5	Outline the concepts of Recovery from Deadlock
		1.3	Analyze the concepts of CPU Scheduling And Memory Management	1.3.1	Compute CPU scheduling Algorithms
				1.3.2	Distinguish Processors Scheduling and Real Time Scheduling
				1.3.3	Explain Memory Management
				1.3.4	Illustrate Virtual Memory
				1.3.5	Describe the Frame Allocation
		1.4	Analyze the concepts of Files And Secondary Storage Management	1.4.1	paraphrase File Concepts
				1.4.2	State the file Sharing and Protection
				1.4.3	Illustrate the File System Structure
				1.4.4	Explain Directory Implementation
				1.4.5	Compute the Disk Scheduling algorithm
		1.5	Analyze the concepts of Distributed Operating System	1.5.1	List Types of distributed operating systems
				1.5.2	Describe Distributed file systems
				1.5.3	Explain Distributed Coordination
				1.5.4	Prepare Concurrency Control
				1.5.5	Summarize Deadlock Handling

Authors

D. Asir Antony Gnana Singh is with Department of Computer Science and Engineering Bharathidasan Institute of Technology, Anna University, Tiruchirappalli, Tamil Nadu, India. He received his B.E and M.E degree in Computer Science and Engineering from Anna University, Chennai, Tamil Nadu, India in 2005 and 2008 respectively. He has published a good number of research papers in International Journals and conferences. His research interests are data mining, wireless networks, parallel computing, mobile computing, computer networks, image processing, software engineering, soft computing, teaching learning process and engineering education. He has participated and co-coordinated the faculty development programmes in India and abroad. He is a Review/Editorial committee member of several reputed journals and also he is a Member of ISTE, IET and IAENG.

E. Jebamalar Leavline is with Department of Electronics and Communication Engineering, Bharathidasan Institute of Technology, Anna University, Tiruchirappalli, Tamil Nadu, India. She received her B.E, Electronics and Communication Engineering in 2005 and M.E in Applies Electronics in 2008 from Anna University, Chennai, Tamil Nadu, India. Also she is a M.B.A graduate in Education Management. She has published a good number of research papers in reputed International Journals and conferences. Her research interests includes image processing, signal processing, VLSI design, data mining, teaching learning process and engineering education. She is a Review committee member of several reputed journals and also he is a Member of ISTE and IAENG.