Emphasis on the Cognitive Framework in Teaching – Learning process in Engineering Education: An Empirical overview

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Abstract

This paper proposes a cognitive framework based on the proposed teaching and learning in engineering education that integrates the affective aspects of learning. Since the last half of the 20th century, the World has been experiencing rapid transformation in the field of Engineering Education, led by the changing Knowledge society. In the present context learning sciences focuses on learning and learners in addition to teaching and teachers. The goal is "to understand the cognitive and social processes in a better way that results in the most effective learning, and to use this knowledge to redesign classrooms and other learning environments so that people learn more deeply and more effectively". This paper explores the literature on direct teaching behaviors and cognitive development that may help foster student learning. A number of teaching attributes such as organization, expressiveness, enthusiasm and rapport/interaction have been found to have a positive relationship with indicators of student- learning and student persistence. Designing challenging teaching units that encourage skills such as independent thinking, experimentation and communication is the objective of an engineering education. Finally we discuss the experiments being made in our institution to make engineering education effective through experiential learning.

Key words: Teaching – Learning Process, Engineering Education, Cognitive Development, experiential learning.

I. INTRODUCTION

Engineers play a vital role in the prosperity of a nation. Therefore, providing effective engineering education is of utmost importance where the task of the engineering educators is to ensure that the expected educational goals are achieved (Malan, 2000)[1] . In other words there is an increasing concern trying to make learning more effective for engineering students (Carberry, Lee, & Ohland, 2010)[2]. One of the important goals of engineering education is to produce graduates who have the appropriate level of engineering content knowledge and skills such as the ability to manipulate processes, solve problems and produce new knowledge (Gondim & Mutti, 2011)[3]. These are also the primarily learning outcomes for the cognitive domain identified by Bloom (Anderson & Krathwohl, 2001)[4].Teaching-learning process is a means through which the teacher, the learner, the curriculum and other variables are organized in a systematic manner to attain pre-determined goals and objectives. These correspond to the graduate attributes which emphasizes on analyzing solving and using knowledge to build system and creation.

II. Literature Review

Lewis(2009)[5] in his study summarized that Current expectations of engineering students are not only that they have the ability to learn, to achieve and to create but also to have the ability to be empathetic, self-starters, critical and creative thinkers.

The affective dimension of learning is important not only because achieving a certain level of affective skills is important by itself but is sometimes critical towards acquiring the desired cognitive learning outcomes of education, engineering education included (Picard *et al*., 2004; Strobel *et al.,* 2011; Hassan, 2011)[6].

Fredricks, Blumenfeld, & Pari*s*, (2004)[7] in their study found that a classroom is a place where engineering students are engaged in learning as well as socialization process. Thus, an engineering classroom is often charged with socialization "affects" such as positive and negative emotions or feeling of acceptance or rejection that could support or hinder learning (Ormond, 2000).

According to another study by Cruickshank & Fenner, (2007)[8] other desirable affective outcomes may also be experienced during classroom interactions such as teacher's positive attitude, respect, valuing other's point of view in the form of appreciation which can promote enthusiasm for learning.

III. The Need for Powerful Teaching - Learning Environment in Engineering Education

Engineering Education should offer conditions needed to optimize learning and promote the transfer of knowledge and skills. Authenticity is an important issue which should be addressed in the design and development of learning environments. Learning environments need to reflect the potential uses of knowledge that pupils are expected to master, in order to motivate in solving problems and prevent the knowledge from becoming inert. In addition, teachers should stimulate pupils to engage in active knowledge construction. This calls for open-ended learning. Learning which focus on a mere transmission of facts, co-operation and interaction in the classroom are important in order to foster the acquisition of skills, problem solving skills, and social relations.

Finally, since the groups of learners are generally heterogeneous with mixed learning ability, differentiation is considered to be one of the key criteria for effective classroom practice. Teachers are expected to adapt the educational setting to the needs and capabilities of the individual pupils. There have been many attempts over time to categorize learning outcomes. These are broadly referred to as taxonomies of learning and can be useful ways of stating what students are expected to achieve. The taxonomy of learning objectives begin at the lowest level with the simplest activities and progress upward through stages with increasing complexity. The most widely applied taxonomy is the Blooms taxonomy.

Fig 1 and 2 shows the application of Bloom's taxonomy in Engineering Education and quality of learning outcome achieved.

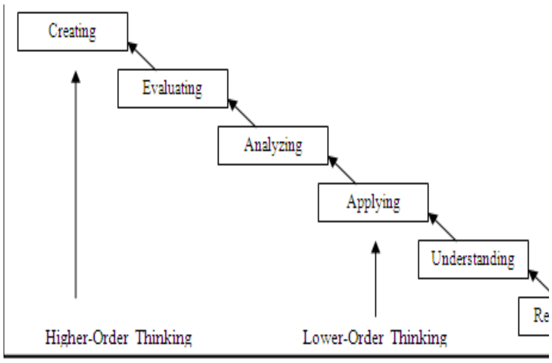

Figure 1- showing the teaching-learning environment in Engineering Education (Bloom, 1950)

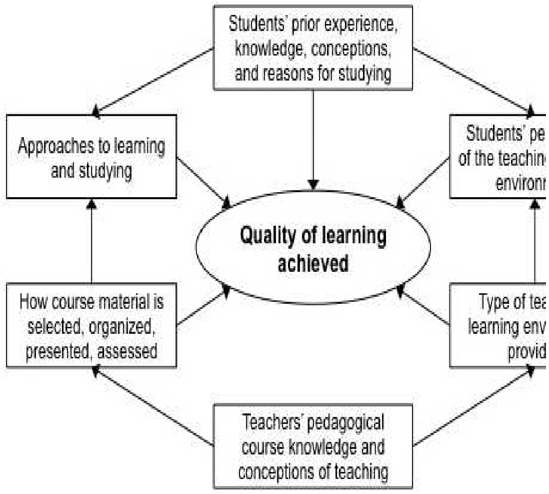

Figure 2- Process of Learning (Stabbins, 2000)

IV. Application of Piaget's Model to Engineering Education

Piaget's has defined the learning cycle of an individual into four groups: Sensorimotor period, preoperational period, concrete operational period and Formal operational period. The importance of the formal operational stage to engineering education is that engineering education requires formal operational thought. A person in this stage starts to think and comes out with inventive ideas. The person invariably resists following somebody's ideas. Many of the 30 to 60 percent of the adult population who have some trouble with formal operational thought appear to be in a transitional phase where they can correctly use formal operational thought. Engineering students in transition appear to be able to master engineering course (Pavelich, 1984)[4].This probably occurs because what they are learning during their engineering courses may not assist their formal operational thought processes and hence they fail to use this knowledge in all areas of their life. There are also a small number of engineering students who are still in the concrete operational stage and therefore will have difficulties in pursuing engineering. These students may make it through the curriculum by rote learning, partial credit, doing well in lab, repeating courses, and **so** forth. Concrete operational students can be identified during repeated administration of tests with novel problems in the same course.

V. Classroom Implications

Fig .3 shows that in a classroom environment, there are many variables that influence and contribute to learning. When creating and implementing a learning environment, it is imperative that the teachers try to not only create a setting that promotes learning, but also need to understand each student. Classrooms are widely diverse and complex. Students learn differently at various developmental levels. Teachers who properly manage their classrooms and establish expectations will be able to incorporate diverse teaching philosophies and create an excellent learning environment for each student. It is important that teachers create a learning environment that encourages students to do their best and makes learning interesting. This creates a motivational climate within the classroom. There are two factors that are critical to motivate students, **value and effort**. *Value* measures the importance of a student's work to himself and others. A student must be made to understand that the work they are performing is worthwhile. *Effort* is the amount of time and energy students put into their work. Understanding the value of academic tasks and the effort needed to complete those tasks can motivate students to perform better in the classroom environment. For this Classroom Management and student involvement are key enablers.

Students have to be involved in the transition from output based education to outcome based education through a process of educating them on the need to transition in view of the global recognition of their program of study and the long term advantages of gaining knowledge Faculty has to lead the way with a willingness to put the efforts in the right directions and lay the foundation for an ambience for quality oriented teaching learning process and their outcomes. The shift is imperative from the output based measures such as the quality of results in examination to outcome based education and has to be initiated by the faculty team. Like in Gurukul system, contribution of faculty in debating and deliberating on the pedagogical aspects of education is a crucial aspect. This will lead to evolution of the teaching methods to continuously improve the effectiveness of the learning of the successive batches of students. Bringing in swift changes in the syllabus and keeping the learning relevant to the current needs, and suggesting infrastructural improvements in laboratories and training modules are the key responsibilities of the faculty group.

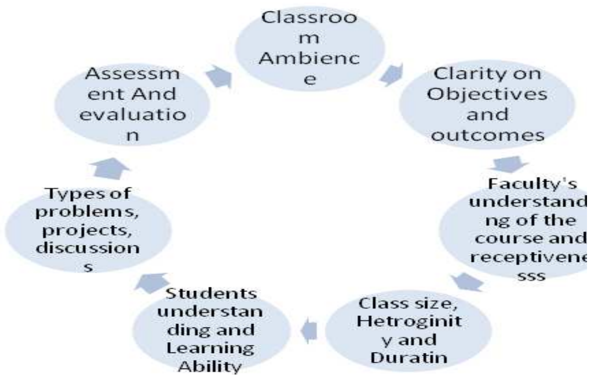

Figure 3- Model of Engineering Education

VI. **Cognitive Development Implied in the Classroom ("Piaget's Theory")**

Piaget's theory of Cognitive development has far reaching implications for curriculum development and teaching methodology. The teaching materials and the learning activities should be those that are appropriate to each of the cognitive developmental stages of the learners.

- Teachers should carefully assess the current stage of a child's cognitive development and assign tasks for which the child is prepared. The child can then be given tasks that are tailored to their developmental level and are motivating. (Flexibility in courses)
- Teachers must provide children with learning opportunities that enable them to advance through each developmental stage. Teachers should maintain a proper balance between actively guiding the child and allowing opportunities for them to explore things on their own to learn through discovery.(experiential learning)
- Teachers should be concerned with the process of learning rather than completing the course work.
- Students should be encouraged to learn from each other. Hearing others' views can help breakdown egocentrism. It is important for teachers to provide multiple opportunities for small group activities.
- Piaget believed that teachers should act as guides to children's learning processes and that the curriculum should be adapted to individual needs and developmental levels. Mentoring students properly will help in achieving the objectives.

VII. Curriculum Design and Development Process

In order to achieve cognitive development in class room curriculum design frameworks have to be thought over with the learning abilities and learner preferences as the central focal point. Fig .4 shows the feature that must be incorporated in the curriculum that is both futuristic in its outlook as well as grounded on fundamental knowledge areas and basic principles. The curriculum should therefore be:

- Well balanced to include the theoretical foundation along with a tilt towards practice and experiential learning, to achieve learning outcomes.
- Focusing on the learning outcomes with the idea of minimum inputs and maximum capabilities and abilities to apply learning to real life scenarios and issues arising out of the knowledge use and applications.
- Providing a great degree of flexibility allowing students to gain grounding on their own discipline along with interdisciplinary knowledge and skills.
- Designed with the idea of building a continuum of knowledge rather than modules that are not integrated with each other and synching with the overall theme of the curriculum design objectives.
- Designed to consider the cognitive abilities of the learners with an idea of making learning a fun activity rather than a serious and life threatening phase of the learners.

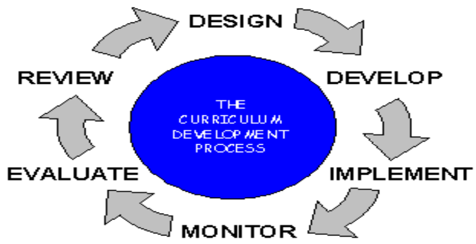

Figure 4- Curriculum Design and Development Process (Van Tassel, Baska 1987)

VII. Major trends in the Teaching – Learning Process

The teaching – learning process is the major academic activity in the institutions. Academic processes are hinged on the teaching- learning process adapted as the practice in the institutional settings. Teaching with passion and learning with fun can build the effectiveness in the academic journey of the students. The Teaching – Learning process started in the ancient periods of civilization called Guru-Kula system of education with one tutor and one or few selected “Shishyas”. In this phase the student shadowed the teacher and learnt the knowledge, skills and abilities through a process of serving and gaining. Teachers were revered as role models and worshipped as being the deities of knowledge. In medieval periods, education and the teaching- learning process was transformed into one-to-many model, where one teacher taught many students. This phase was popularized with the help of formal methods of transcribing the knowledge and by bringing out the books published by teachers to help in systematic learning.

Inspirational leadership became the source of motivation and the pupil was given the privilege equivalent to that of the family members and the major drivers of relationship between the teacher and the student was the love and affection showered on the pupil. Students used memory based techniques to gain knowledge and reproduce the same in the process of tests, examination and oral recitation of the concept learnt.

Imagination and creativity was relegated to the goals of achieving perfection and excellence in the acquisition of coded and systematized knowledge. In this phase, sincerity to the purpose of learning and being committed to the teaching- learning was rewarded with recognitions and awards to the learners.

From fig.5 and 6 it is understood that for deep learning to happen, cognitive processing of information and, as a result, a change in the learner's knowledge is necessary as an important component of cognition. Kirschner, Sweller and Clark (2006)[9] viewed learning as building on theoretical knowledge and working with long-term memory to engage in cognitive activity.

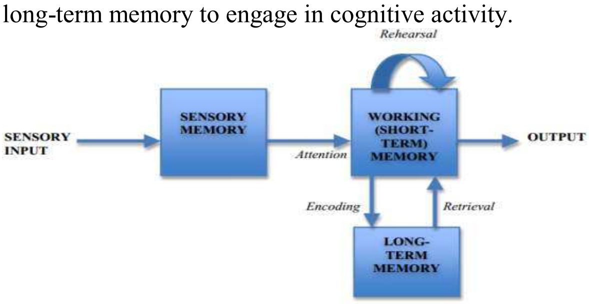

Figure.5-Structure of Human Cognition Kircher,2006)

- ***Long-term memory*** constitutes the dominant structure of human cognition and provides a huge information and knowledge base accumulated through prior experiences. Long-term memory is central in order to engage in cognitive activity. For example, compared to novices, experts draw on extensive experience stored in their long-term memory to solve problems, while novices lack proper schemas to integrate new information (Bransford, Brown and Cocking, 2000)[10]. Hence, learning in this cognitive interpretation – occurs when the long-term memory is altered.
- ***Working memory*** is in charge of conscious information processing. It is limited in duration and capacity when novel information is processed. For example, information that is processed, but not rehearsed, can be lost within seconds. Only a limited number of elements can be processed or stored. Cognitive load theory suggests that discovery learning within a complex learning environment generates a heavy working memory load that is detrimental to learning (Paas, van GogandSweller, 2010)[11].On the other hand, the limitations do not apply when familiar information that is already stored in long-term memory is brought back into working memory.

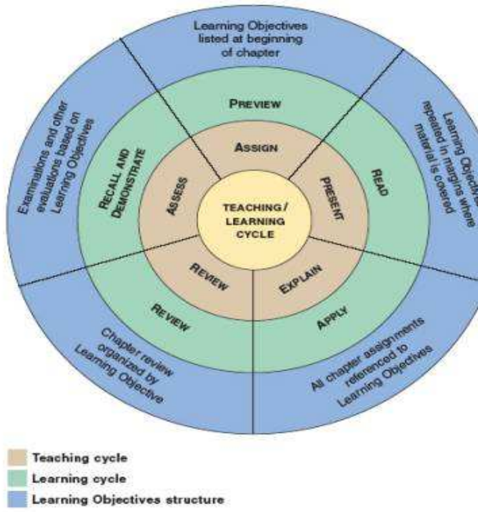

Figure 6 Teaching – Learning Process (Brown and Cocking, 2000)

IX. Learner and Learning Style

Why do movies make more impact on the minds of the people compared to the learning process in the institution? The answer to this question lies in the root of the Cognitive Psychology. Cognitive scientists have researched on learning style over the last several years and have classified learning styles in the following different ways. It indicates that children retain 20% of what they hear, 40% of what they see and hear and 75% of what they see and do.

Modern day learners need to learn in a differentiated manner from the learners of the yester years. Today's generation the Gen- Y prefers active learning modes to passive learning modes. Action – based learning and self – engaged learning styles are observed to be dominant modes of learning. The focus is shifting definitely from the teacher – centric education to the learner centric education. Activity based learning and learning styles involving a participatory approach to learning fascinates the learners of this century. The positioning of the BIG picture in the mind of the learners is an important motivational aspect of learning styles observed. Leask

(1999) has studied how these personal preferences affect the learning style of each individual. From his study we conclude that students' learning styles also highly depend on:

a) **Structured vs. spontaneous learning**: The degree of flexibility an individual wants during the learning process, that is, how much structured and well-organized or spontaneous the individual wants the learning material.

b) **Autonomous vs. Instructor-led learning**: The degree to which the individual wants autonomy or another individual (teacher) to get involved in the learning process. Opportunities created motivate students to build systems from the knowledge they have gained. With the advent to ICT (Information and Communication Technology) and big data the days of instructor – led learning are vanishing. Instructor needs to be a facilitator and guide the learners.

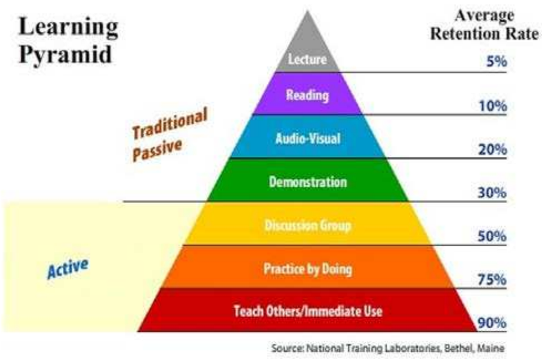

Figure 7 - **Learner and Learning Style**

Learning through self, learning through networking, learning through experimenting, Learning through experience, learning through self- guided, problem- based learning, learning through Technology, are the style that will decide the future course of the teaching – learning in the engineering education. Effective, outcome based higher education cannot rely exclusively on memorization through drill and practice, or high-stakes standardized testing. Instead, education has to create learning environments that allow students to make sense of what they learn and process content deeply so that they can apply their understanding to solve problems (Bransford, Brown and Cocking, 2000).

X. Our experience:

We have tried to shift from the traditional teaching learning to experiential learning. About 50 credits are reserved for experiential learning and the learners are appreciating this shift. There effort in getting information putting them together and coming with their own ideas is showing positive results. The counseling through their mentors has helped in identifying drawbacks and providing them solutions to improve their learning ability. The counselors help their mentees to choose courses, drop or withdraw courses in particular semesters. Introduction of interdisciplinary electives and courses make learners know how they can apply their gained knowledge to real life situations. Students are provided with opportunities to learn through seminars, assignments, group discussions etc. related to the subject being taught as per the curriculum. They are also motivated to fabricate working models, charts and also attend subject seminars of interest in other institutions.

The Learning is being made student centric by supporting the students at various levels. The students are encouraged to interact with the faculty and the counselor regularly when there is a need. Self learning components have been introduced in which innovative topics are given in groups to bring out the system design and learning capability of students. The academic activities concentrate on helping the students to gain an excellent theoretical knowledge base and in the development of skills to implement them. The latest teaching aids from multimedia equipment to simulation techniques ensure a thorough learning process.

Computer -assisted Learning is one of the effective methods in teaching and learning process particularly in core subjects. It is used for visualizing, analyzing and understanding complex topics and in interpretation of large data.

Project – based learning is mostly used for self learning to improve the ability of student to use knowledge gained. Being a technical institute, this method is extensively used to provide practical evidence of the theory learned. Students are asked to prepare projects involving application of the concepts, principles or laws learnt. The teacher guides the students at various stages of developing the project to give timely inputs for the development of the model.

Motivation is created by conducting competition among students to carry out multidisciplinary projects.

XI. Conclusion

Engineering education equip students with a wide range of skills needed in innovative and changing knowledge societies and economies. In addition to subject-based know-what and know-how, this includes skills for thinking and creativity as well as social and behavioral skills. Mastering a wide range of skills will facilitate students becoming true lifelong learners, able to face and act upon the uncertainty of the future. These skills for innovation, together with engineering education that are multidisciplinary in nature are receiving more and more attention worldwide.

Based on an extensive body of literature, this paper suggests that teaching matters for student's learning. As educators, we certainly need to have an open mind to new ideas and to teach our students to do the same, in order for them to learn how to develop a critical attitude towards stimuli around them. One of the factors that may contribute to this phenomenon is the lack of a teaching and learning model for supporting the utilization of the affective dimension in the teaching for cognitive learning. We have found that, students appreciate allowing them to learn which enhance their cognitive ability rather than enforcing teaching on them.

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