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Epistemological Study to Evolve Creative Learning Process for Engineering Students

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To provide the means of obtaining knowledge is the greatest gift that can be given to mankind. In professions like engineering "the meaning of *knowing* has shifted from being able to remember, to find and use it." For the past century, education system all over the world served merely as a selective function. It was founded on scoring marks by memorizing concepts, missing a world filled with inspiration, creativity, vision and the full spectrum of human drives and desires. This paper summarizes the outcome of a research work, for evolving a Creative Learning Process (CLP) for engineering studies. The model was aimed at eliminating the limitations of Bloom's taxonomy and Revised Bloom's taxonomy in fostering creative thinking and problem solving skills among students. The new paradigm evolved was represented as a three dimensional sphere, containing 14 peripheral elements, with motivation as an additional initiating central element. Four epistemological theories, metaphysical, skeptical, critical and naturalized epistemology were used as an analytical frame work for the study. Vignettes were used as a means of implementing the concept in classrooms. This paper presents one element 'Diagnostic learning' and one vignette in detail, for explaining the difficult concept of "mass" to the students. The CLP model was tried out in an engineering college in South India and the results were extremely encouraging.

Keywords: Creative Learning, Creative Thinking, Problem Solving Skills.

The nearest effort to utilize creative power for T-L process was the Bloom's taxonomy (Bloom, 1956). This triune model separated the learning process into three domains, cognitive, affective and psychomotor. Cognitive domain received maximum patronage of educationists. The Revised Bloom's Taxonomy (Anderson, 2001), a two dimensional model, was a step forward in creative learning process. It incorporated affective domain, psychomotor domain, and creativity by adding the fields 'meta cognition', 'procedural knowledge' and 'create,' respectively.

As a first step in the study, Bloom's Taxonomy (BT) was introduced in an engineering college in South India. After practicing BT for two years, the revised Bloom's taxonomy (RBT) was introduced, for three selected classes of 60 students each. A study was done on the effectiveness of BT and RBT as a pedagogy model for engineering studies. (*Details of the study are not discussed in this paper.*) The study showed that BT and RBT were very effective in promoting higher order learning, but could not stimulate creative thinking among students. Teachers preferred BT to RBT, because of its simplicity for adoption and practice. Both models were based on the concept of hierarchal mode of learning and depended on linguistics as a means of classification. Creative content was less in both T-L processes.

The objective of the study was to evolve a new model of T-L Process with Creativity as the driving force, for disseminating knowledge, without the step by step learning requirement of BT and RBT. It also wanted to eliminate too much dependence on knowledge of English language for developing and implementing the model.

Because of the novelty of the study and total involvement of teachers and students, only one college in South India agreed to implement the new concepts of pedagogy. Teachers of this college were given continuous training in Bloom's Taxonomy and its revised version before practicing theses models. Later, orientation classes on creativity, lateral thinking and brainstorming were conducted for the faculty. As the teachers were already practicing BT and RBT, it was not difficult for them to have the insight to arrive at the elements evolved for creative learning. Once the required ambience was created, several brain storming (Delphi method)sessions were conducted for evolving the new Creative learning Process .A set of difficult engineering concepts were collected from 800 students of different branches , by using questionnaire. 45 Vignettes were developed by teachers, using the creative elements of the new model. Out of this, 34 vignettes were selected by an expert panel and used for class room discourse by visual presentations using smart classrooms equipped with multimedia facilities. For evaluating the effectiveness and reliability of the new model, statistical tools like ANOVA, and profile analysis were used. Expert evaluation was done to find the content validity.

Limitations

The Study was limited to one college in India, having students of average cognitive abilities. The initiating element 'Motivation' was excluded from the study. The study was limited for a period of three years, out of which two years were used for training the teachers and also creating a good learning ambience by introduction of BT and RBT as pedagogy. The new model was practiced for one year, consisting of two semesters.

Following four epistemological concepts were used as a framework for formulating the new CLP model:

1. Metaphysical epistemology: When Plato (ca 360 BC) tried to distinguish between mere belief and knowledge in "The Theatetus," as an attempt to answer the skeptical doubts, he initiated a distinct province of inquiry, called 'epistemology'. Main concern of this new branch of philosophy was determining the nature, scope, sources and the limits of human knowledge.

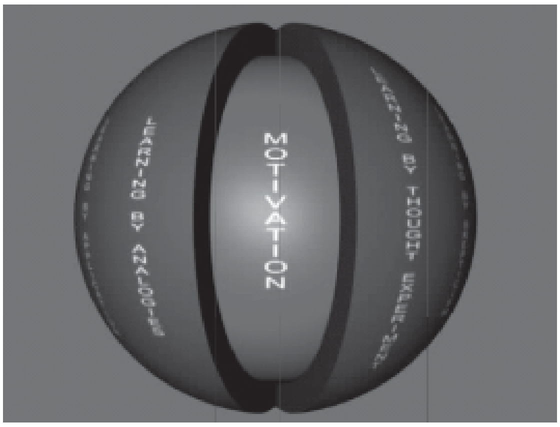
2. Skeptical Epistemology: Descartes (1595-1650) was a famous French mathematician, scientist and philosopher. "I think, therefore I exist"- (Latin: *Cogito, ergo sum*) - from the 'Discourse on method.' Descartes refused to admit the existence of anything real until he could establish that it is known and not merely believed to exist.

3. Critical Epistemology: The concept of Critical Epistemology was postulated by Keith Lehrer, (1990) in his 'Theory of Knowledge'. Here, we begin with common sense and scientific assumptions about what is real and what is known. The approach is exploring how we know the things we think we know, but we do not.

4. Naturalized epistemology: According to Quine (1975), "the Nature of natural Knowledge" in *Guttenplan* epistemology can be viewed in a new setting contained in natural science, as a chapter of psychology. It eliminates traditional epistemology as the distinct province of inquiry whose concern is the nature, the limit and sources of knowledge in favor of science or psychology.

Procedure followed for evolving and implementing the CLP in classrooms.

Step–1 Identification of difficult concepts in different subjects: Initially a list of difficult concepts was collected from about 800 engineering students using questionnaire and data sheet. Part of this list is given below as Table



Subjects	Concepts
Electrical , electronics and Communication engineering	Electro magnetic field, Working of Capacitor and LC oscillator, Concept of eclectic flow, mass, Faradays laws of electromagnetism Ac and Dc in electrical engineering Conductor, Semiconductor in electronics. Working of Microwave oven Ohm's Law Motor , Transformer, and generator

Step- 2: The trained teachers were subjected to a series of brainstorming sessions for evolving the elements of the model. The initial 40 element model suggested was reduced to 23 after critical review of the researchers. After a 6 moths pilot study among 60 students, the model was further refined to the following 14 elements(in alphabetical order): Analogy, Application, Bionics, Corrective learning, Diagnostic learning, Dichotomy, Exploration, Insight, Modeling and simulation, Parallel learning, Relationship, Skepticism, Symmetry and Thought Experiment. Motivation was a core element for initiating the process.

3-D Spherical representation of the Model: The model evolved, was conceived as a three dimensional sphere. All the 14 elements were embedded on the surface of this sphere, ensuring equal accessibly of individual element or group of elements from the center element. Consequently, there was no need for hierarchical learning, because the students could adopt any element, or group of elements, once they are motivated (centre element), to start the creative leaning process. The three dimensional model is diagrammatically represented above.

Step-3: This model was implemented using vignettes written by the teachers, and vetted by an expert panel of the subject. A group of 16 teachers in three classes (176 students), used the new model for a period of one year (two semesters). The results were evaluated using statistical tools and the expert panel. Out of 45 vignettes written by teachers for the 14 elements, the expert panel chose 34, for classroom use.

Overview of the epistemological framework of 14 elements

Element-I Learning by Analogies: Analogies are helpful because they make complicated situations more accessible and simple. Hamilton, a philosopher, who taught that knowledge is not absolute, and is relative to and shaped by human senses, said that "to get at truth, imperfect logical devices such as models and analogies are necessary." Many difficult concepts were explained to the scientific community by the original discoverers was by means of analogies.

Element– 2 Learning by Application: In the evolution of epistemology, human beings devised tools first to solve their problem of survival; the tools were mere application of a concept to solve problems in hunting. No theories were developed, first to design such a device. *This shows that learning can start with application first and knowing the basic principles involved can follow later.*

Element–3 Learning by Bionics: This falls under Naturalized epistemology, where the limit and sources of knowledge is nature. As part of evolution, nature has solved many problems, in its own way. Nature's ideas and problem solutions, which have stood the test of time over millions of years of evolution, are good method of grasping knowledge, because nature itself is an all revealing laboratory.

Element–4 Corrective Learning: If wrong concepts are captured initially, the process of unlearning the false knowledge will reinforce retention power of knowledge, provided the why of what was wrong is understood. Corrective learning is this creative process.

Element– 5 Learning by Dichotomy: Every knowledge in this world has two opposing pairs. Light - darkness, good - evil, zero –one, matter- antimatter, electron – proton, motor- generator, electricity – magnetism etc. Learning the opposite concept is an easy way to understand the one on hand.

Element– 6 Learning by Exploration and Discovery: Lateral thinking is the core concept in this element. Alternate solutions are sought and optimum one is discovered, by exploration. This journey exposes the student to many related concepts, and reinforces the knowledge.

Element–7 Learning by Insight: Gestalt psychology argued that learning and problem solving are, like perception, functions of organizational processes. *How to behave in a particular situation may elude subjects until they see various components of the tasks in the appropriate relationship. The subject may take a number of perspectives on the situation, until the correct one emerges, a "moment of insight". Finally the problem is solved, and in a flash, the subject knows what to do.*

Element–8 Learning by Modeling and Simulation: Modeling is an imitation of reality which can be in the physical form (*analogue simulation.*). When the problem involved are too complex, it is converted into mathematical model or, use the mathematical model to develop computer simulation.

Element–9 Parallel Learning: Many concepts can be learned, by studying the main characteristics in one context and then extending the features to other contexts. A good example is learning motor and generator and transformer all working on the same principle.

Element–10 Learning by Relation ship: Most of the fundamental concepts have interrelationship like Electricity and magnetism. So if learning focus on these interrelationships, it will be easy to grasp the knowledge, by anchoring one concept to another.

Element–11 Skeptical Learning: This method follows Descartes' "*method of doubt*" where by he began investigation of knowledge by considering as false whatever was subject to the slightest doubt- a sure way of avoiding the error.

Element–12 Learning by Symmetry: In Einstein's theories, the creative spark was the idea of symmetry. Several concepts would become easy to assimilate if symmetry, which is nature's way of engineering, is established.

Element–13 Learning by Thought Experiment: For some concepts, it is very difficult to carry out experiments physically and prove or disprove a hypothesis. In such cases, it is possible to imagine certain experiments and make conclusions. Einstein used this method many times for developing concepts on time and space.

Element-14 Diagnostic learning: Teaching Learning Process will not be effective, if there is no feed back system inbuilt into the process. Diagnostic learning enables the teacher to discover individual misconceptions of the students and lead them to real knowledge. It is like a Doctor asking a patent about symptoms of the sickness, and diagnoses the disease for effective treatment.

An illustrative example of the Vignette written for explaining the concept of mass is given below.

Vignette- Concept of mass

A. Statement of the Problem.

For many students mass was just 'quantity of matter', With this limited knowledge, they were not able to appreciate concepts like inertia ,difference between quantum mechanics and Newtonian mechanics etc. dealt in engineering classes.

B. Solution.

The solution of this problem was accomplished by adopting diagnostic learning process. In this vignette, a series of questions (framed by the teacher) and answers (given by the students in the class room) are listed. The learning process is framed in 4 stages, each stage representing specific learning strategies involving other elements in the CLP model.

Stage 1 Diagnostic Questions and answers-Table 2

The remark column is by the teacher. (Abbreviation DQ for diagnostic question, SQ for stimulating question).

Table- 2: Diagnostic Learning- Concept of Mass

No	Questions	Answers	Remark
1.	What is mass?	It is the quantity of matter	DQ
2	Quantity means Volume? Weight?	Volume and density	DQ
3	More Volume, more mass? 1m^3 Cotton heavier than ½ m^3 of lead?	No	Analogy
4	What is density?	Mass per unit volume	Factual
5	Then are you not assuming that you know what is mass	Yes	Do
6	Can you think of it differently?	Is it weight?	SQ
7	What is weight?	F=mg, Force with which gravity pulls the matter	Factual, Partly correct
8	So, can you relate mass and weight?	Yes, m =F/g, force per unit gravity	Insight
9	If there is no gravity, then no mass? like in outer space ?	Yes	Corrective Learning.
10.	So, what could be mass?	I don't know	End of thought process

Stage 2:

At this stage a different strategy was followed; the students were exposed to a set of Leading fundamental concepts to discover knowledge as shown in Table 3 below:

Table- 3: Discovery of Knowledge – Mass (continued)

1	What causes motion?	Force	Factual
2	Why some objects accelerate?	F= ma or a=F/m	Factual
3	So, if mass is less, more acceleration?	Yes	Factual
4	For the same force, applied to two objects, if acceleration is different, what is the conclusion?	More acceleration less mass, less acceleration, more mass.	Thought Experiment
5	Can you look at the mass concept if this phenomenon is considered	Yes-mass is related to motion, more mass , more difficult to accelerate it and vice versa	Insight, relationship
6	Imagine two balls made of different materials, same size, on the ground. Could you find which has more mass, with out weighing it?	Take a stick or bat, smash them with equal force. One will move further away from the other. This ball will have more mass	Thought experiment, Analogy.
7	If inertia is a measure of resistance to the motion, can you now explain mass?	Yes, Mass is a measure of its inertia, the tendency to resist acceleration, if a force acts on it.	Discovery of Knowledge!

Stage 3: Strategy followed- Dichotomy, and Explorative Learning

Now, we wanted to take the students to other related subjects like gravity, difference between mass and weight, quantum theory, and to get other ideas on mass and gravity. Let us see how this was done.

Table- 4: Explorative Search of Knowledge-Mass (Continued)

Stimulating Questions	Acceptable answers	Strategy followed
1 What is the difference between weight and mass?	Mass is a fundamental (intrinsic) property, weight is a force that pulls a body directly toward a nearby astronomical body. It's magnitude at any location depends on the value of 'g' there.	Dichotomy Learning
2 Differentiate the units for both	Weight is Vector, because force is vector Mass is scalar, Mass unit-Kg, Weight-Newton	Dichotomy Learning
3 Like weight, mass also can vary?	Yes, As per special relativity theory of Einstein, mass of an object vary with speed-This effect is perceptible only for speed approaching that of light. In Newtonian mechanics, mass is assumed constant...	Stimulating Question Skeptical
4 Is there any modern view on mass,consider ing Newton's view as a bench mark?	Yes. Newton focused on how things work, and not why. Recent research has focused on *why* , that is origin of mass , which will extend to particle physics, mysteries of dark matter, which makes up 25% of the Universe	Explorative Learning

5 What is the foundation of the modern view?	It is more intricate, and is based on a standard model. This model is based on a mathematical function called a *Lagrangian* Which represent how the various particles interact.	Explorative Learning
6 What is Lagrangian?	It is an energy function 'T' for kinetic Energy and potential energy. Sum of these functions called Hamiltonian H=T+V. Equally important is the difference between the two functions called Lagrangian L=T-V. To define the motion of an object, H or l is to be solved	Explorative Learning
7 How Lagrangian leads to the concept of mass?	From this function, by following rules known as relativistic quantum theory, physicists can calculate the behavior of the elementary particles, including how they can come together to form compound particles such as proton.	Explorative Learning.

Stage 4: Strategy Followed- Explorative Learning By Lateral Thinking, Convergent And Divergent Thinking:

In this stage further exploration was done with lateral thinking aided by stimulating questions like: What is relativistic quantum theory, What is elementary particles, What is standard model, What is string theory, What is extended standard model , What is quantum theory of gravity ....?

All these questions were explorative in nature. Only good motivation will propel a person to find out answers to these questions, and leading to the threshold of new knowledge. Students were taken to this stage to make them realize that with all scientific advancement, there were unknown realms of knowledge not discovered by human being.

This is the ultimate journey one can take in the field of epistemology

Comment: Scientists hope to find a good explanation on the phenomenon of mass, when a multi billion project called Large Hadron Collider (LHC) at the European particle physics lab, CERN, Switzerland, is started up in 2009.

Reliability and Validation:

The reliability of the New CLP model was tested using statistical tools including Profile analysis, with a group of 176 students, in different engineering subjects. It was found that the group (85 students) which took the course under the new model scored significantly higher marks than the group (91students) which took the traditional pedagogy model.

The profile analysis (Figure.1) showed that for all subjects, the group taking the New CLP pedagogy model scored extremely well in all subjects, compared to the group who were given traditional methods of pedagogy like lecture and demonstration classes and Bloom's taxonomy.

Figure 1 The profile analysis showed that for all subjects

Evaluating the *Effectiveness* of CLP model for imparting higher order Creative thinking process as reflected in question papers set by teachers.

In addition to profile analysis, study was done on the teacher's ability to design a good evaluation system, giving emphasis to higher order learning based on the new model.

For this purpose, a comparative study was done on 30 Question papers set by the University (where teachers were following traditional pedagogy practices) under which the College was academically affiliated and 30 questions papers of the same engineering subjects set by teachers of the college (where the study was done) for the internal assessment. The parameters used were the domains as given by B T, Knowledge and comprehension for lower order learning and application, synthesis, and evaluation for the higher order learning, giving increased weight age as the questions moved from the lower to the higher learning. The marks given were: 5 for knowledge level, 10 for comprehension, 20 for application, 25 for synthesis and 25 marks for evaluation. The analysis was done in 2 ways, first by taking the total percentage of marks for each question paper and then by taking the percentage of marks that was obtained for each level.

Table 5: Comparative Study of Question Papers Set By University Teachers and the College on Evaluating Higher Order Learning

Average % of marks	Knowl edge	Compre hension	Appli cation	Analysis	Synthesis	Evalu ation	Score for lower order	Score for higher order
University	10.46	56.87	14.98	9.92	6.80	0.97	67.33	32..67
College	8.80	15.60	31.90	17.0	14.20	12.50	24.40	75.60

The data showed that questions set by the university teachers practicing traditional pedagogy, were not focused on higher order learning areas like Application, Synthesis and Evaluation(score only 32.67), where as the college teachers practicing CLP, gave great emphasis in evaluating the higher order creative learning content of the subjects, scoring 75.60 . This study showed the effectiveness of the new CLP model in imparting higher order creative learning process among students.

Content Validity of Vignettes:

An expert panel consisting of the following vetted the content of the vignettes.

1. An eminent Professor in Physics from a reputed Science College in Kerala.

2. Head of the department of Electronics and communication of the college where the study was conducted.

3. A retired Professor in Mechanical Engineering from IIT, Chennai

4. A professor of education from National Institute of Technical Teachers Training and Research, Chennai.

5. General Manager of an electronic industry in Kerala.

Learning Outcome of Students.

Learning outcome of the vignettes used for creative Learning Process was very important for asserting the operational validity. For this purpose, the teachers who were taking the classes using vignettes recorded the learning outcome of each class, and discussed with the expert panel that had done the content validity of the vignettes. This enabled evaluation of the operational validity of vignettes.

Conclusion

The CLP model evolved after the study was found to be very useful in fostering creative talents among engineering students. The vignettes used for the process were beneficial to the teachers as well as students, for evaluation of creative higher order learning domains. It also made complex concepts easy and simple for knowledge assimilation by students. The model could be tried in more engineering colleges located in different parts of the country, for evaluating its effectiveness among a spectrum of students of varying cognitive abilities. More vignettes could be written, covering all subjects taught in engineering, and made available to the students and teachers, so that learning process can take place not only in the class room, but also in home environment, stimulating the insight and curiosity .

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