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Analysis Of Question Papers In Engineering Courses With Respect To Hots (Higher Order Thinking Skills)

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ABSTRACT

It is generally perceived that a substantial number of engineering faculty are still unaware of alternative educational methods, and many who are aware of them choose not to incorporate them into their approach to teaching. There are several likely reasons for this inertia, aside from the inevitable human resistance to change. The primary focus of imparting information is restricted to fulfilling the course requirements and, the upcoming term end examination. It is imperative to adopt a change from teaching to learning paradigm engaging the students in Higher Order Thinking Skills. Knowledge and technological advancements are changing the role of engineering and engineering faculty in the society. Engineering Education reforms need to focus on inductive teaching and stimulated learning. Students should be taught critical thinking skills and creative thinking skills to keep pace with the rapidly changing engineering profession.

This paper reports the study done to test and explore the faculty awareness of Bloom's Taxonomy of Educational Objectives in the cognitive domain and Higher Order Thinking Skills (HOTS) and to evaluate question papers set by engineering faculty with respect to HOTS as proposed by Bloom's Taxonomy. Various active learning strategies to enhance critical thinking skills and creative thinking skills of the students are recommended for use by the faculty in their interactions with the students.

Keywords: Bloom's Taxonomy; Higher Order Thinking Skills (HOTS); Critical Thinking; Creative Thinking; Analysis of Question Papers

INTRODUCTION

Globalization, demographics and technological advances are changing the role of engineering and technology in society (Duderstadt, 2008).[1] Outsourcing which was restricted to call centers in India, hitherto, is now seen in engineering design, R& D and even in innovation. The change that is required is a shift from routine, repetitive aspects of engineering to higher order and more value added activities. According to former US Secretary for Education, Richard Riley the top ten jobs that will be in demand in 2020 did not exist in 2010.[2] It is predicted that by 2020 information will double every 72 hours. A change needs to occur in the current post primary education from knowledge acquisition and lower cognition to knowledge application and higher cognition knowing when and how to use that knowledge.[3] Learners of the 21st century need to develop new skills and that the three R's, reading writing, and arithmetic are no longer enough. According to Gluck in Peters (1994)[4] we must add in our list the three C's Computing, Critical Thinking and Capacity for Change as well.

Faculty and educators should not allow the students to wonder whether they have been learning anything that would actually serve them in the workplace, upon graduation.[5] Traditionally engineering curriculum focused on deductive instruction where the instructors, delivered lectures with limited application of the principles to real life engineering. Deductive instructional approaches have limitations in preparing engineers for a changing global society as required by NAE (National Academy of Engineering), (2005).[6] Engineering Education reforms need to focus on inductive teaching and situated learning which involves student engagement in real life problem solving as

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opposed to disconnected lectures fulfilling curricular requirements.[7] An inductive approach with situated learning involves inquiry learning, problem based learning, vignette instruction and case based instruction. (Prince and Felder, 2006).[8] The pedagogic techniques practiced in many engineering colleges and technical institutions in India, though are aimed to meet the goal of cognitive development amongst the students but often end up in meeting the requirements of an examination system designed to test the rote memory rather than developing problem solving skills. (Sowmya Narayanan and Adithan. M, 2012).[9]

Academic Staff College at VIT University has been conducting a number of Faculty Development Programmes (FDP'S) on Bloom's Taxonomy and Revised Bloom's Taxonomy to train its faculty on the use of them as an assessment and pedagogical tool. In order to improve student's higher order thinking skills, teachers should employ suitable teaching and assessment methods. Anderson and Krathwohl (2002)[10] categorises knowledge as factual knowledge, conceptual knowledge, procedural knowledge, and meta cognitive knowledge. These are remembering, understanding, analyzing, evaluating and re organizing in the cognitive process dimension. In the present study the focus is on Bloom's original taxonomy only. Bloom's taxonomy deals with three dimensions viz cognitive, emotive and psychomotor. In this research Bloom's taxonomy of educational objectives pertaining to cognitive domain alone is considered and reported. There is a need to identify the teacher's ability to prepare questions at various levels of the taxonomy and offer the requisite training programmes to fulfill that need.

The purpose of the study was to know the extent of awareness of Bloom's Taxonomy and Higher Order Thinking Skills (HOTS) amongst the engineering faculty and to analyze the end- semester question papers with respect to HOTS as proposed by Bloom's Taxonomy. The study brings out the importance of critical thinking and creative thinking amongst the engineering faculty and how these skills can be incorporated in the teaching-learning process.

BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES OF THE COGNITIVE DOMAIN

Benjamin Bloom in 1956 proposed a Taxonomy of Learning Objectives of the Cognitive Domain. This work has been extensively used and referred to by researchers, teachers, educationists, curriculum planners and examiners, almost at all levels of education in several disciplines. (Anderson and Sosnaik 1994).[11] The objectives are placed in a hierarchy starting from Knowledge to Evaluation Fig 1. The first three levels namely knowledge, comprehension and application are generally known as LOTS (Lower Order Thinking skills) while, analysis, synthesis and evaluation are termed HOTS (Higher Order Thinking Skills). The levels have been a stairway leading many teachers to encourage their students to climb a higher level of thought. However, according to the authors, in engineering education, the level "application" needs to be positioned in HOTS since students of engineering and technology are expected to know the engineering and technological applications of the various theories, principles and concepts that they learn while studying the various subjects. There is a need to sensitize the engineering faculty on this critical aspect.

Bloom's Original Taxonomy

Bloom's Revised Taxonomy

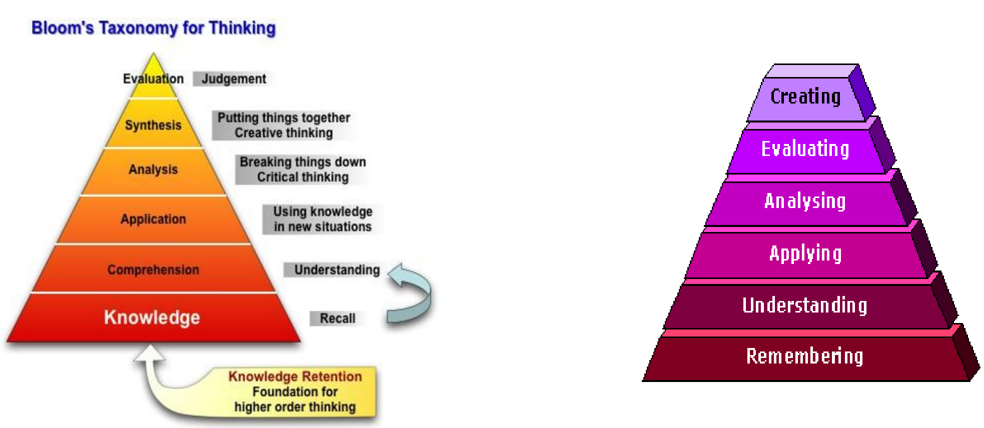

Figure 1. Bloom's Taxonomy of Educational Objectives (Cognitive Domain)

The taxonomy is hierarchical; each level is subsumed by the higher levels. In other words, a student working at the application level has also mastered the material at the knowledge and comprehension level. (University of Wisconsin, Teaching Academy, 2003) [12].

When the instructor desires to move a group of students through a learning process, utilizing an organized framework of Bloom's Taxonomy can be quite helpful. It has been linked with Multiple Intelligences, problem solving skills, Creative and Critical thinking and more recently technology integration skills.

In engineering subjects teachers can develop the critical thinking skills of the students using Bloom's Taxonomy. A teacher can ask more questions at the analysis and synthesis level than a simple recall of facts at the knowledge level. "Students can incorporate the ability to analyze, synthesize or evaluate the concepts for which there should be an increase in their learning and understanding resulting in enhanced retention of the subject matter taught and ability to apply them in real life situations."(Cruz, 2004)[13]

BLOOM'S REVISED TAXONOMY LEVELS
AND CORRESPONDING ILLUSTRATIVE VERBS (Appendix 1)

Levels	Illustrative Verbs:
Knowledge: Can the student recall or remember the information?	define, duplicate, list, memorize, recall, repeat, reproduce, state
Comprehension: Can the student explain ideas or concepts?	classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase
Application: Can the student use the information in a new way?	choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write.
Analysis: Can the student distinguish between the different parts?	appraise, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.
Synthesis: Can the student create/develop a new product or point of view?.	assemble, construct, create, design, develop, formulate, write.
Evaluate: Can the student justify a particular statement or decision?	appraise, argue, defend, judge, select, support, value, evaluate

Thus, Bloom's Taxonomy will serve as an effective tool guiding the faculty to arouse the curiosity of learners in their subjects. A faculty needs to develop a repertoire of questions that generate higher order thinking skills such as the following. What do you already know? What do you think really about this situation?

CRITICAL THINKING AND CREATIVE THINKING

"Critical thinking is the disciplined mental activity of evaluating arguments or propositions and making judgments that can guide the development of beliefs and taking action."(Huitt 1998)[14] Evaluating is, considered equivalent to critical thinking and this focuses on making assessment or judgment based on an analysis of a statement or proposition. Learning the process of critical thinking might be best facilitated by a combination of didactic instruction and experience in specific content areas.

"Creative thinking requires an individual to look at parts and relationships (analysis) and then to put these together in a new and novel way, as well as looking at the elements and the whole in a new perspective altogether". (Huitt) [14] "Techniques that are often taught as part of critical thinking process is generally more linear and serial, more structured, more rational and analytical and goal oriented. Techniques taught as part of creative thinking exercises tended to be more holistic, and parallel, more emotional and intuitive, more creative, more visual, more kinesthetic. This distinction relates to what is sometimes referred to as left brain thinking (analytic, serial, logical, objective) as compared to right brain thinking (global, parallel, emotional, subjective)" (Springer and Deutsch, 1993)[15]. Engineering faculty needs to be exposed to these concepts during the Faculty Development Programmes.

ENHANCING CRITICAL THINKING SKILLS

All higher educational institutions (HEI's) and Universities should enhance critical thinking skill amongst their students and should be held accountable for to provide this when students are enrolled and pursuing a degree programme. "Active learning, which includes activities such as discussion, debates, role plays and cooperative learning encourages critical thinking and helps the students retain technical contents better. When active learning activities are employed, students have to use a deep level approach when learning course contents, which results in students using higher order thinking skills. (Annette Mallory Donava, 2003)[16]

OBJECTIVES OF THE STUDY

The aim of the present study was twofold. First was to test and explore the faculty's awareness of Bloom's Taxonomy and HOTS, and the second was to evaluate/analyze their question papers with respect to HOTS as proposed by Bloom's Taxonomy. In a higher institution or university set up, it is expected that % of questions in end-semester examinations constituting HOTS should be about 70-75% and students are expected to attain this level of competency and learning outcomes.

RESEARCH POPULATION

For conducting this study the research population identified were faculty teaching engineering courses from four colleges of engineering and technology in the region; three colleges from University affiliated systems and Schools of Engineering from VIT University itself.

Responses with respect to extent of awareness of Bloom's taxonomy and its various levels were obtained from a total of 104 faculty members across various disciplines/subjects in engineering and technology. The sample population involved in the study in the pre and post workshop surveys remains the same i.e. 104 faculty.

RESEARCH METHODOLOGY

The study is based on the analysis of responses of faculty participants. In the first part of the research study a Questionnaire (as in Table 1) was administered to the faculty members to elicit their awareness of Bloom's taxonomy and its various levels. The reason for this is it is generally observed that engineering faculty in Indian technical institutions and colleges of engineering are not aware of Bloom's taxonomy, since they have not gone through any formal structured pedagogical training programme prior to their appointment as engineering faculty. Then, sessions on Bloom's Taxonomy were held as part of training programme to enhance and to improve their awareness and knowledge of Bloom's taxonomy as a pedagogical tool. Training programmes on Bloom's taxonomy were conducted for faculty working in the engineering colleges, functioning within a University Affiliation system as well as to faculty working in different schools at VIT University. Number of question papers analyzed and the mean % of questions involving LOTS and HOTS are given in Table 5.

After the training programme the questionnaire with the same contents was administered to know the extent of their awareness. Responses were analyzed with respect to both quantitative and qualitative aspects and summarized in Table 2.

The second part of the research study was the analysis of end- semester question papers prepared by the faculty. For this purpose a proforma (Table 3) was developed and given to faculty. Faculty were asked to study the question paper set by them and identify to which category a particular test item/question belongs to and indicate the marks allotted to the question. The data obtained was tabulated as in Table 3. The % of questions of various levels of the cognitive domain i.e. knowledge and comprehension constituting LOTS and application, analysis, synthesis and evaluation constituting the HOTS are shown as in Table 4.

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Table 1. Questionnaire Administered Before And After Training Sessions On Bloom's Taxonomy

Name:	Date:
Designation:	
School:	
Name of the theory Subject/Course you are handling this Semester Dec. 2011-April 2012	
Name of the Programme and Branch:	
Have you attended any lecture/sessions on Bloom's Taxonomy earlier?	
Name some levels of Bloom's taxonomy?	
What is LOTS? Expand	
What is HOTS? Expand	
Are you aware of alternate approaches to learning?	
If yes, list the alternate approaches you know.	

Table 2. Analysis Of Responses Received

No. Of Responses Received	**104**
Colleges Participated	**No. Of Faculty Involved:**
• Sahrdaya College of Engineering & Technology, Kodakkara affiliated to University of Calicut	26
• St. Ann's College of Engineering and Technology, Chirala affiliated to Jawaharlal Nehru Technological University, Hyderabad	27
• Abdul Hakeem College of Engineering, Melvisharam affiliated to Anna University, Chennai	26
• VIT University (Engineering Schools), Vellore	25
Total	**104**

	Before The Training Sessions	**After The Training Sessions**
	(no. of responses)	
• Have you attended any lecture/session on Bloom's Taxonomy earlier?	Yes -11 (10.6 %) No-93 (89.4%)	
• How many levels are there in Bloom's Taxonomy?	95 (91.3%) participants did not know the no. of Levels.	5 (4.8%) participants did not know that there are six levels even after the training session.
• What is LOTS? Expand	98 (94.2%) participants did not know the expansion of LOTS.	15 (14.4%) participants didn't recollect the expansion of LOTS even though they attended the training session.
• What is HOTS? Expand	98 (94.2%) participants did not know the ex pansion of HOTS.	14 (13.5%) participants didn't recollect the expansion of HOTS even though they attended training session.
• Are you aware of alternate approaches to learning?	Yes 55 (52.9%) No 49 (47.1%)	83 (79.8%) 21 (20.2%)

Table 3. Analysis Of Question Papers With Respect To Higher Order Thinking Skills (HOTS)
And Lower Order Thinking Skills (LOTS)
(numbers indicate the marks allotted to the question)

Subject:						
Analysis of Question Papers with Respect to Bloom's Taxonomy						
Date:						
	LOTS		**(Higher Order Thinking Skills (HOTS)**			
Test Item/ Question No.	**Knowledge**	**Comprehension**	**Application***	**Analysis**	**Synthesis**	**Evaluation/ Judgement**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Total:						

Actual	**Desieable**
Know + Comp = %	20 – 25 % 30 % (max)
App + Ana + Syn + Eva = %	70 – 75 %

*For the analysis, "Application" level is considered as a Higher Order Thinking Skill. In engineering education, students study many principles, rules, laws, and equasions and it is desireable that they also know and learn their practical applications in different areas of engineering and technology.

The question papers were categorized into 7 disciplines of engineering and the average of % marks of questions in LOTS and HOTS were calculated and tabulated as shown below:

Table 4. Analysis of Term End Question Papers Number of Semester End Question Papers that were analyzed: 85

DISCIPLINE NAME	Average % Of Questions/Marks pertaining to LOTS	Average % Of Questions/Marks pertaining to HOTS
Mechanical Engineering	54.1	45.9
Electrical Engineering	36.7	63.3
Electronics and Communication Engineering	44.1	55.9
Applied Sciences	36.1	63.9
Bio Sciences and Technology	72.0	28.0
Computer Science and Engineering	48.9	51.1
Information Technology	59.7	40.3

The above information is shown in the form of bar chart (Fig 2)

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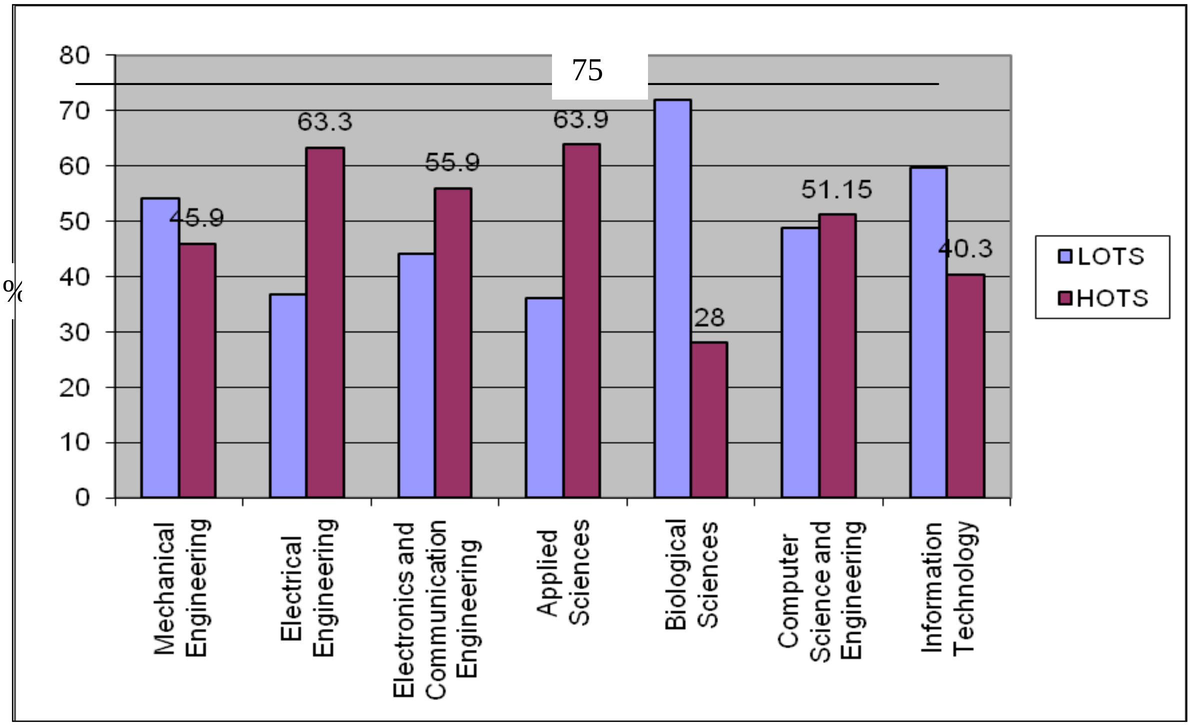

Figure 2. Analysis of Term End Question Papers In Respect Of Subjects across Various Disciplines % indicated is in respect of HOTS only (75% line indicates the expectation of the University i.e. proportion of questions constituting HOTS should be 75%)

Table 5. Analysis Of % Questions Involving LOTS And HOTS Set
By The Faculty Of Various Engineering Colleges And Engineering Schools

The findings are as follows:

Name Of The College	Number Of Question Papers Analysed	Mean % Of Questions Involving Hots
*Sahrdaya College Of Engineering And Technology	25	58
*St Anns College Of Engineering And Technology	23	51
*Abdul Hakeem College Of Engineering	17	45
**VIT University (Engineering Schools)	20	53
Total	**85**	

***** Engineering Colleges functioning within an university affiliation system, but located in different towns
****** Schools of engineering functioning within VIT University campus.

RESULTS AND DISCUSSION

HOTS (Higher Order Thinking Skill) is the ability to make judgments, analyze contents and synthesize information into coherent forms of communication and present such information to others. There are many examples/activities which illustrate the Higher Order Thinking Skills (Appendix 1). These aspects are discussed during the training sessions organized by the authors during this study. The awareness and knowledge of engineering faculty regarding Bloom's Taxonomy, LOTS and HOTS is abysmally low and hence there is a need to organize more training programmes of this kind.

The importance of setting good quality question papers with a high proportion of HOTS needs to be stressed amongst the engineering faculty during the faculty development programmes. A substantial number of engineering professors are still unaware of alternative educational methods, and many who are aware of them choose not to incorporate them into their approach to teaching. There are several likely reasons for this inertia, aside from the inevitable human resistance to change. On the job training preferably under the guidance of a senior faculty will also be of help in adopting the new methodologies. A total of 104 faculty participants across several disciplines of engineering were involved in this study. 89% of faculty participants have not attended a lecture/training session of this kind before and 91% of the respondents were not aware of the different levels in Bloom's Taxonomy. 94% did not know the expansion of LOTS and HOTS before the training. This proportion is reduced to 14% after training. Before the training 47 % of the respondent faculty members were not aware of the alternate teaching methods like role plays, quizzes and use of demonstrations. After the training this percentage reduced to 20%. Thus the training sessions have given sufficient awareness and inputs in helping the faculty to understand Bloom's Taxonomy and its levels also various alternate strategies towards learning.

An analysis of end -semester question papers with respect to assessing the proportion of questions involving HOTS pertaining to engineering subjects has yielded interesting results. There is an expectation in engineering education as in VIT University that % of questions/test items involving HOTS should be about 70-75% and the balance 25-30% could be from LOTS, so that skills such as Problem Solving, Critical thinking and Creative thinking are imparted and evaluated in engineering education.

Questions based on HOTS are more (above 63%) in the case of disciplines like Applied Sciences; and Electrical Engineering. Questions based on HOTS are less in the case of disciplines like Bio Sciences, Computer Science, Information Technology and Electronics and Communication Engineering and Mechanical Engineering. In respect of these disciplines the low % of HOTS could be due to the nature of curriculum presently followed at the University and/or due to inadequate exposure of faculty to the concept of HOTS in the teaching-learning process.

CONCLUSIONS

1. Faculty should be trained to set more questions testing the Higher Order Thinking Skills of the students. The faculty should pose questions to encourage critical thinking and creative thinking rather than asking students to recall from memory, facts or the general information.
2. The problems of the real world of work and engineering practice do not lend themselves so easily to a set of well defined questions. Most of the time the practical problems in the world of work remain indeterminate and are problems not too well defined confining to any equation or formula. This ability to formulate, evolve and understand the practical problem itself is quite a challenging task. These aspects need to be addressed at the highest level of Bloom's Taxonomy. We find that faculty is not able to train their students with abilities required to meet the challenges of the present and future engineering profession. This stresses the need and importance of faculty development programmes on critical thinking and creative thinking.
3. The proportion of questions pertaining to HOTS is much less than the expectation of the university/higher education institutions. Faculty needs to be sensitized on this pedagogical issue, since the analysis of question papers was done by the faculty themselves who have set the question papers.
4. Faculty need to be given more training sessions and orientation on Bloom's Taxonomy and also to be exposed to alternate and innovative teaching and learning processes. This would help the students think critically and creatively whereby subjecting the students to higher order questions would yield effective results.
5. Achievement at the lower levels of taxonomy, knowledge and comprehension learning can be facilitated by presenting facts, procedures and information to learners. For this instructional methods include lectures, viewing videos, and use of multimedia learning packages/ tutorials. However, achievement of skills at higher levels of Bloom's Taxonomy requires more active strategies. This requires the student to interact with information. Thus there must be opportunities for active learner participation, continuous practice and finally feedback and interaction. Majority of the questions in subjects like Bio Sciences and Technology, Computer Science, Information Technology, Electronics and Communication engineering and Mechanical Engineering require recall or memorizing ability and factual information, only testing surface knowledge. Faculty members in these disciplines still focus on lower cognitive process skills while assessing students' learning outcome.
6. The instructional methods that the faculty could use to promote HOTS would be in-class active learning exercises, paraphrasing, use of analogies, real-time examples, frequent interaction with faculty, summarizing one or two peer reviewed papers, solving ill- structured and open ended problems and

frequent writing assignments. Also, alternate teaching methods like use of analogies, group discussion, animation, case studies analysis and problem based learning will be useful in improving the higher order thinking skills of the students.

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APPENDIX 1

BLOOMS TAXONOMY

Benjamin Bloom created this taxonomy for categorizing different levels of competency to be developed in learning a subject. The taxonomy also provides a useful structure for categorizing test questions.

Competence	Skills Demonstrated	Question Cues		
	Lower Order thinking Skills (LOTS)			
Knowledge	• Observation and recall of information (from memory) • Knowledge of dates, events, places • Knowledge of major ideas • Knowing of subject matter	**List Define Tell Describe Identify**	**Show Label Collect Where Tabulate**	**Quote Name Who When**
Comprehension	• Understanding information • Grasp meaning • Translate knowledge into new context • Interpret facts, compare, contrast • Order, group, infer causes • Predict consequences	**Summarize Describe Interpret Contrast**	**Predict Associate Distinguish Estimate**	**Differentiate Discuss Extend**
	Higher Order Thinking Skills (HOTS)			
Application	• Use information • Use methods, concepts, theories in new situations • Solve problems using required skills or knowledge	**Apply Demonstrate Calculate Complete Illustrate**	**Show Solve Examine Modify Relate**	**Change Classify Experiment Discover**
Analysis	• Seeing patterns • Organization of parts • Reorganization of hidden meanings • Identification of components	**Analyze Separate Order Infer**	**Connect Classify Arrange Divide**	**Compare Select Explain**
Synthesis	• Use old ideas to create to create new ones • Generalize from given facts • Relate knowledge from several areas/ disciplines • Predict, draw conclusions	**Combine Integrate Modify Rearrange Substitute**	**Plan Create Design Invent What If?**	**Compose Formulate Prepare Generalize Rewrite**
Evaluation (Judgment)	• Compare and discriminate between ideas • Assess value of theories, presentations • Make choices based on reasoned argument • Verify value of evidence • Recognize subjectivity	**Assess Decide Rank Grade Test**	**Recommend Convince Select Judge Measure**	**Discriminate Support Conclude Compare Summarize**

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