

Qualitative Assessment of Software Engineering Examination Questions with Bloom's Taxonomy

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Abstract

Context: Question items are intended to evaluate students for various skills and knowledge acquired during the process of learning. The knowledge and skills acquired by students are typically organized through educational taxonomies. Bloom's taxonomy is one of the widely used taxonomies for various activities in an education field. However, there is no comprehensive understanding on how it can be employed in Software Engineering (SE) Education. **Objectives:** To identify the gaps in building/setting a question paper to assess the students in the context of Higher Order Cognitive Skills (HOCS) for a course on software engineering. **Method/Analysis:** The question papers of a course on software engineering conducted by various universities are collected and analysed with Bloom's taxonomy. All Question items are analyzed and assessed across six cognitive levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation which capture diverse cognitive skills from memory recall to problem solving. The analysis is performed for classifying the question items asked in software engineering examination conducted by various universities. **Findings:** Around 174 question items from various question papers were selected and analysed according to Bloom's Taxonomy. Results of the analysis shows that most of the question items asked in the examinations for a course on software engineering test only Lower Order Cognitive Skills (LOCS) such as Knowledge and Comprehension. Very few percentages of questions are asked to test the higher order cognitive skills (HOCS) such as Analysis, Synthesis, and Evaluation. **Novelty/Improvement:** The course on software engineering deals with the various skills and methods for the software development. In particular, most of the software development processes such as analysis, design, construction, testing etc. required higher order cognitive skill. Thus, the percentage of questions to assess such skills must be increased in the question paper. This work can be extended to provide automated generation of a question paper with Bloom's Taxonomy.

Keywords: Assessment, Bloom's Taxonomy, Engineering Examinations, LOCS, HOCS, Software Engineering

1. Introduction

Question items asked in an examination play an important role to assess student's skills. It is an essential instrument for assessment and evaluation of students. Assessment is one of the important activities of a teaching - learning process. Student's skill can be assessed by different activities carried out in the academic session¹⁻³. Written examination tests the academic performance of the student. Despite a significant increase in performance evaluation, some issues like testing of intellectual skills remain unresolved. An assessment of the skills acquired and knowledge gained through a course on Software

Engineering is equally useful to academicians as well as industry professionals. Academicians can use the results of the assessment to devise appropriate interventions in case of the assessment results do not conform to the set learning objectives. Employers of fresh graduates may use the results of the assessment to design pre-induction training programs. One way to perform such an assessment is to analyze question papers used for conducting examinations because it includes the most relevant information required for it.

This section reviews some of the earlier applications of Bloom's Taxonomy. One of the most frequent uses of the taxonomy has been to classify curricular objectives and test

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items in order to show the breadth, or lack of breadth, of the objectives and items across the spectrum of categories presented earlier research⁴⁻¹¹. Bloom's taxonomy has been used for defining learning outcomes and objectives¹²⁻¹⁴, curricular development¹⁵⁻¹⁸ for the various courses. Computer Science related learning taxonomy¹⁹⁻²² is developed on the basis of Bloom's framework. This paper also summarizes the related techniques used for the text classification as follows: 1. A decision tree method²³ to classify the health and non-health related data. 2. A classification methodology based on the classical Naive Bayesian classifier is proposed to categorize the persons into different classes based on different attributes relevant to their educational qualification²⁴. 3. A comparative analysis on the evaluation of classification algorithms in the prediction of student's performance²⁵. 4. A framework for user assessment on precision imprecision utilization (why and when) and maintenance over semantic query processing²⁶. 5. An Agile Teaching-Learning Methodology for Engineering Education²⁷. 6. Measurement of university student's IT capabilities²⁸.

A question paper is typically designed to test students on diverse range of skills such as to recall a learned topic or to apply a learned method to solve a particular problem. Further, question papers include questions from all the knowledge areas that are expected to be covered in a course on Software Engineering. In this paper we classify questions and select question items to set the question paper to conduct an examination for a course on software engineering. For on-going research, we have selected the syllabus designed for the undergraduate program (B. Tech. in Computer Engineering) and the course Software Engineering. This course is included in Third year of the B. Tech. Program in our university.

2. Material and Methods

2.1 Course

Computer Science and Information Technology (CS/IT) is one of the rapidly growing fields. Software Engineering is one of the core Knowledge Area (KA)²⁹ introduced in undergraduate degree course in the CS/IT education. In particular, Software Engineering is one of the courses designed for third year students in the discipline Computer Engineering, Computer Science and Engineering, Computer Technology, Information Technology etc. running by various universities. This course is very essential for academics as well as industry. Software Engineering is

not only a course but also a special discipline in higher education. For our study and research, we have collected question papers of software engineering examinations (particularly, semester end examinations) conducted by various universities.

2.2 Taxonomical Framework

In 1956, Dr. Benjamin Bloom headed a group of educational psychologists, developed a cognitive framework in learning domains. Bloom found that over 95% of the test questions students' encounter requires them to think only at the lowest possible level i.e. the recall of information. Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order which is classified as evaluation.

Bloom has defined six cognitive levels in his taxonomy for educational objectives as shown in Figure 1, these levels are: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. These levels are hierarchically arranged; Bloom believed that the mastery level in the first level is essential to achieve the second level and so on³⁰. Bloom identified four principles that guided the development of the taxonomy³¹: 1. Categories should be based on student behaviors, 2. Categories should show logical relationships among the categories, 3. Categories should reflect the best current understanding of psychological processes, and 4. Categories should describe rather than impose value judgments.

Assessment is a process of making a decision based on rules and standards. Assessment is an on-going process, which combines teaching and learning process. The basic characteristics of an assessment are: 1. Assessment is a data collection process for making decision for individual or group. 2. Test is a part of assessment, and 3. When assessing students, teacher will actually measure the level of competency to determine a mastery level for each stage of teaching and learning that have been created.

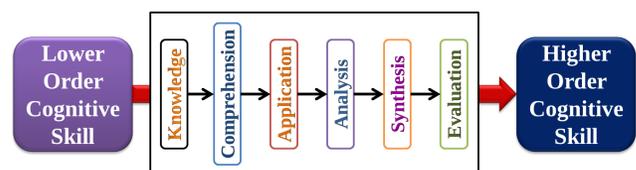


Figure 1. Hierarchical levels in cognitive domain of bloom's taxonomy.

2.3 Software Engineering and Bloom's Taxonomy

Cognitive levels of the Bloom's Taxonomy with respect to software Engineering are described in the following subsections:

2.3.1 Knowledge

Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge represents the lowest level of learning outcomes in the cognitive domain. Sample questions that may be asked to assess this skill are:

2.3.1.1 Recognize the different phases of the software development process

Description: The theme of this question is that various keywords are listed to the students, some may represent the phases of the software development and others are unrelated words to software process model. The students have to recognize the correct keywords or a phrase which represent phases of the software development process. The cognitive skill required to answer this question is recalling the name of phases in software development process. The process of recalling a previously learned material falls in the Knowledge category.

2.3.1.2 Define software engineering. Give the characteristics of software?

Description: In this question the standard definition of software engineering is expected from the students. Also, the list of characteristics of the software is expected. Both answers can be memorized and reproduced; no additional skill is required to answer this question. The memorizing skill is the first level of the cognitive skill.

In the Bloom's Taxonomy, the Knowledge category embodied both noun and verb aspects. The noun or subject matter aspect is specified in the knowledge's extensive subcategories. The verb aspect is included in the definition given to knowledge in that the student is expected to be able to recall or recognize knowledge³².

2.3.2 Comprehension

Comprehension is defined as the ability to grasp the meaning of material. This may be shown by translating

material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond the simple remembering of material, and represent the lowest level of understanding. Sample questions may be asked to assess this skill are:

2.3.2.1 State and explain evolutionary life cycle models

Description: To answer this question, students require describing evolutionary life cycle model. To explain some concepts, an understanding of those concepts is required without which no-one can describe a concept in his own words. Hence, this question tests comprehension skill.

2.3.2.2 Describe the role of quality assurance activities in the software process

Description: The process of describing something requires additional skills other than just remembering. The process of describing some concept requires acts of elaboration and providing additional information along with the main points.

2.3.3 Application

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension. Sample questions that may be asked to assess this skill are:

2.3.3.1 Compute the function points for the following data set: Inputs = 8, Outputs = 12, Inquiries = 4, Logical _les = 41, Interfaces = 1 and Fi = 41

Description: The expectation from a student to answer this question is to calculate the correct value on the basis of the given data. To do this, student must know the formula to calculate function point and procedure to solve the given problem. The ability to use the formula, method, concept to find the solution for a given problem is termed as application. The student requires application level of cognitive skill to answer such type of questions.

2.3.3.2 *How to use Gantt-chart for planning and controlling small projects?*

Description: Answer to this question requires an ability to use the specific technique or method to plan, control, monitor the progress of the project development process. Students should be able to show the development phases with time line or to show the planning of the short projects. Student must be required to achieve application level skill in the cognitive domain to answer such type of questions.

2.3.4 *Analysis*

Analysis refers to the ability of splitting material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material. Sample questions that may be asked to assess this skill are:

2.3.4.1 *Distinguish the phases of software development process*

Description: To answer this question student must be aware that software development process is a complex task. It is very difficult to handle such a complex and large task by only one person or a team. So, the whole task is divided into number of phases. All phases are interrelated. Students also know the interrelationship among the phases. The task of finding such a relationship among sub divided phases leads to analysis.

2.3.4.2 *Analyse an operation and a method in the context of object-oriented design technique?*

Description: Answer to this question requires the specific way of performing operations or using methods in the given context. It requires more skill than that of application. Students also know association among all. Thus the analysis skill is required to answer such type of question.

2.3.5 *Synthesis*

Synthesis refers to the ability to put parts together to form a new or advanced of the previous one. This may involve the production of a unique communication, a

plan of operations, or a set of abstract relations. Learning outcomes in this area stress creative behaviours, with major emphasis on the formulation of new patterns or structure. Sample questions that may be asked to assess this skill are:

2.3.5.1 *Prepare Software Requirement Specification (SRS) for course management system*

Description: To answer this question student must analyse collected data. Student must know the method of preparing the SRS document. The course management system is a new problem/project. So student must understand the various components of the system that is to be developed. So to answer this question different skills are required. Preparing something is the ability of a student to create the new solution. The creativity skill is required to answer such type of questions.

2.3.5.2 *Design and explain the sequence diagram for ATM system.*

Description: To answer this question student must be aware with the concept or method of sequence diagram and how it can be used in the program/project development. Also, student must know about the ATM transactions or services so that it can be represented graphically. Designing something new is a creativity skill. This skill must be achieved by the student to answer this question.

2.3.6 *Evaluation*

Evaluation is concerned with the ability to judge the value of material for a given purpose. The judgments are to be based on certain criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) and the student may determine the criteria or be given them. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all the other categories as well as conscious value judgments based on clearly defined criteria. Sample questions that may be asked to assess this skill are:

2.3.6.1 *In the development of large, embedded real-time systems, suggest five factors that are likely to have a significant effect on the productivity of the software development team*

Description: To answer this question student must be aware with various factors that may affect the overall performance

of the software development team. The experimentation must be carried out earlier and the corresponding outcomes must be found on the basis of which student can suggest someone to follow or implement a strategy which is tested and evaluated earlier. This requires the evaluation skill. It can also be done logically by investigating various similar cases and their results. The comparative study and knowledge is required to answer such type of questions.

2.3.6.2 Suggest how you would go about validating a password protection system for an application that you have developed

Description: To answer this question, student must give personal opinion, experience to suggest a way of validating a password protection system. Student must have evaluated that system, applied some criteria and considered circumstances where it can give good performance. The performance evaluation of something requires evaluating skill. The Bloom’s taxonomy is adopted for various purposes in the teaching learning processes²⁴. According to Bloom, the taxonomy is more than a measurement tool.

3. Results and Discussion

Over 174 questions from Software Engineering semester end examinations are collected and analysed. Table 1 shows the percentage of marks along with the cognitive levels for every question paper. For example, In Question paper 1, 45% Marks questions are asked to test the knowledge level cognitive skill, 48.75% Marks questions are asked to test the Comprehension level cognitive skill and 6.25% Marks questions are asked to test the Evaluation level cognitive skill. Unfortunately, no questions are asked in this paper to check Application, Analysis and Synthesis levels of cognitive skill.

The observations and finding during question paper wise analysis are shown in Figure 2 and the overall cognitive level wise distribution for all question items in all question papers are shown in Figure 3. After complete analysis It is found that 40.67%, 55.04%, 2.25% and 2.04% Marks questions are asked to test Knowledge, Comprehension, Application and evaluation cognitive skills respectively.

Table 1. Paper wise analysis of marks in % along with cognitive levels

Cognitive Level	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5	Paper 6
Knowledge	45.00%	88.00%	25.00%	17.00%	16.50%	52.50%
Comprehension	48.75%	12.00%	75.00%	81.00%	77.50%	36.00%
Application	0.00%	0.00%	0.00%	0.00%	2.00%	11.50%
Analysis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Synthesis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaluation	6.25%	0.00%	0.00%	2.00%	4.00%	0.00%

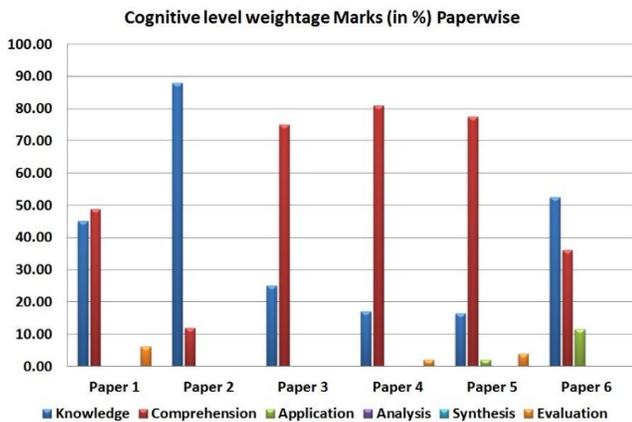


Figure 2. Paper wise analysis across Bloom’s Taxonomy.

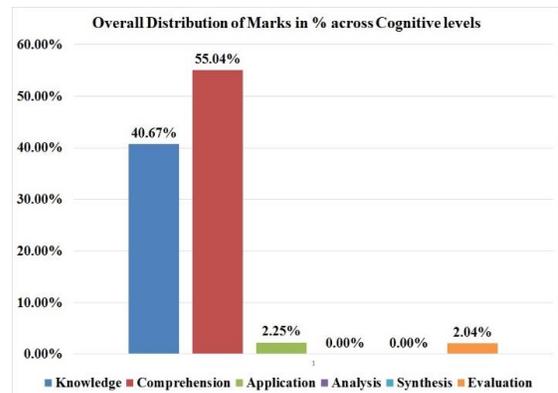


Figure 3. Overall distribution of marks across cognitive levels.

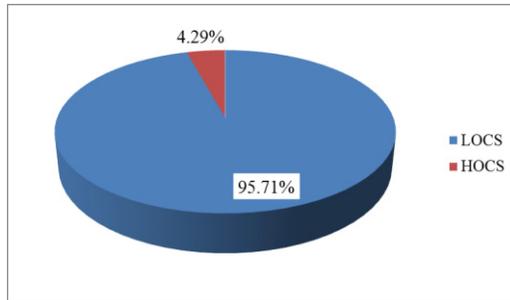


Figure 4. Percent distribution across HOCS and LOCS

4. Conclusion

This paper presents the qualitative analysis of the software engineering examination questions. Some of the major findings during analysis are listed below:

- The levels of cognitive domain help teachers to transform student's skill from the knowledge level to the evaluation level.
- Question paper assessment using Bloom's taxonomy guide to judge the student skill at each level.
- The application of Blooms taxonomy for software engineering question paper assessment is important to set level of difficulty of a question paper.
- From Figure 4, The comparative analysis shows that 95.71% marks questions asked in examinations test Lower Order Cognitive Skill (LOCS) whereas only 4.29% marks question test higher order cognitive skill.

From the above observations we also conclude that the question paper must formulate to focus on the Higher Order Cognitive Skills (HOCS). Our on-going research is focused on the automated testing and generation of the question papers with bloom's cognitive levels.

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