Assessment Patterns in Computing Education

Renumol V.G., Cochin University of Science and Technology, India
Rekha Sunny T, SCMS School of Technology and Management, India

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Abstract
One of the primary objectives of Computing Education is to develop computational thinking skills, which enable the students to solve problems using computers. It requires higher-order cognitive skills, which are more difficult to learn and practice when compared to lower order skills such as memorization and recollection. But to what extent have these higher order skills been tested through assessments in our computing courses? A preliminary study was conducted in this regard in a post-graduate course in Computer Applications, based on Bloom's Taxonomy (BT) on cognitive domain. BT is a well-known taxonomy on educational objectives. A total of 510 questions were analysed using BT keywords and were mapped to the respective cognitive levels based on the question cues. The results show that questions at higher order levels are few when compared with the lower order level questions. Mainly the memorization and recollection skills of students are tested. This paper describes the details and findings of this study.

Keywords: Assessment system, Bloom's Taxonomy, Computational thinking, Question paper setting

Introduction

Computing education necessitates good problem solving and program design skills which are directly related with higher-order thinking skills of students [10]. Nowadays the effectiveness and quality of computing education is questionable. There are many reports which point out the high failure rate and poor effectiveness of computing education courses [4][5].

In any education system, there are three stages, such as, plan the learning-objectives, teaching/instruction and assessment. In these three stages, assessment is the most important since it aims to make judgements about students' and teachers' effectiveness [11]. In effect, assessment can also determine the success of the planning and teaching stages. The most common method to assess the learning outcome and thinking level is written-examination. The success of this assessment method is in setting an appropriate question paper which comprises questions from various difficulty levels especially higher order thinking levels [8]. Higher order cognitive skill items are defined by Zoller & Tsaparlis [12] as "quantitative problems or qualitative conceptual questions, unfamiliar to the students, that require for their solution more than knowledge and application of known algorithms. Such an application may further require (partially or fully) the abilities of reasoning, decision-making, analysis, synthesis, and critical thinking".

In this study, an attempt has been made to discover whether we are testing the higher order thinking skills of students in a post-graduate computing course - Master of Computer Applications (MCA). The data collection has been done from the past five years' university question papers. Bloom's Taxonomy of educational objectives has been chosen as the framework for the analysis of questions, due to its wide acceptance and simplicity in structure.

The entire paper is organized as follows. The next section describes Bloom's Taxonomy, which is followed by the methodology and the analysis results. The last section concludes the paper.

Bloom's Taxonomy

Bloom's Taxonomy (BT) is a well-known taxonomy on educational objectives and it explains 3 domains of learning – Cognitive, Affective and Psychomotor [6]. Cognitive domain deals with knowledge and thinking. Affective domain deals with attitudes and, psychomotor domain deals with physical skills. Previous studies on computing education show that there is a high cognitive requirement for computing education [9][10] and hence BT on cognitive domain is used in this study.

The taxonomy was primarily developed by Benjamin Bloom in order to promote higher order thinking in academic education. Later Anderson et al. revised it by slightly rearranging the higher levels in the cognitive domain (Fig.1). Cognitive domain has a well defined hierarchy of six cognitive levels - Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. Of these 6 levels, analysis, synthesis and evaluation are considered as higher order cognitive levels which require various skills such as critical thinking, decision making, problem solving etc. The current study mainly focuses on the higher levels (Analysis, Synthesis and Evaluation together as a group) and hence the original model by Benjamin Bloom is considered in this study.

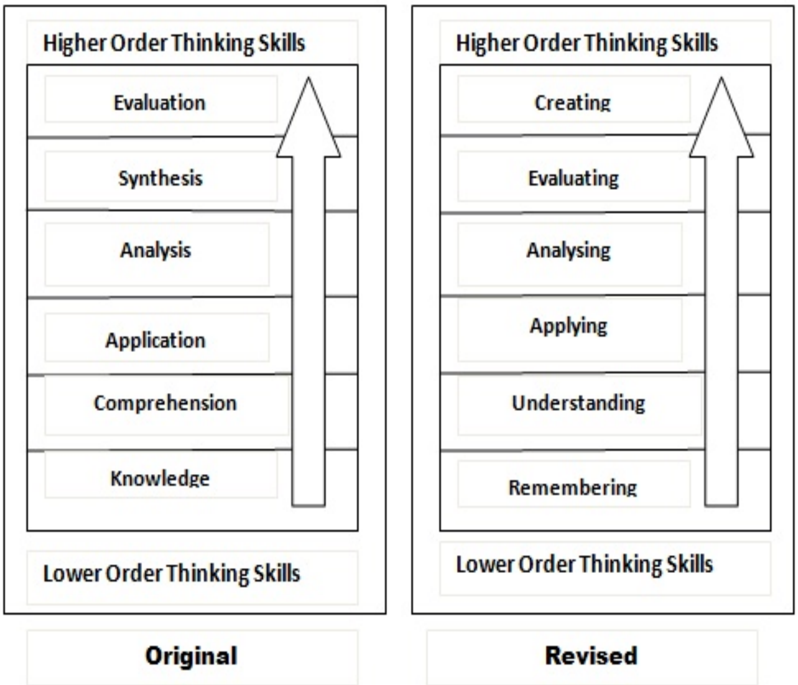

Figure1: Bloom's Taxonomy - original and revised

Knowledge: This is the lowest level of the taxonomy where questions are asked to test whether a student is able to remember the lessons learned. Concepts, definitions, principles, formulas etc. are examples of knowledge level questions. Knowledge of the main ideas being taught can be included in this level [2]. Some of the question cues for this level are identify, describe, name, label, recognize and reproduce.

Comprehension: At comprehension level students need not only be able to recall information but also be able to understand the meaning of remembered material, and explain in their own words or citing examples. Interpret the facts, explain the process and describe the function of each component etc. are examples of comprehension level questions [2]. Describe, summarize, explain, interpret and identify are some of the question cues for this level.

Application: In this level, students should be able to apply and use the knowledge they have learned. For example, students may be asked to solve a problem applying the knowledge they have gained in the class, to illustrate some concept with a diagram or to create a viable solution [2]. Some of the question cues for this level are apply, illustrate, demonstrate and solve.

Analysis: Analysis level requires students to go beyond knowledge and application and actually analyse a problem using their own patterns. Students need to examine and discriminate between the relationships of the component parts of the material. For example, "What factors in the Indian economy are affecting the current price of petrol?”[2] is an analysis level question. Analyse, discriminate, compare, distinguish and break down are some of the question cues for this level.

Synthesis: Questions on synthesis level require students to use the given facts to create new theories or make predictions. Knowledge from multiple subjects can be combined to reach to a new solution or conclusion. For example, a student may be asked to invent a new product, to devise ways to design test hypothesis or to propose a new solution [2]. Some of question cues for this level are synthesise, propose, plan, construct and organise.

Evaluation: This is the highest level of thinking where students are requested to make judgements about the merits of an idea, method, procedure or product. It is the most complex process and requires students to use all the other five levels. Question cues like estimate, assess, select and debate can be used in this level [2].

Methodology

The objective of this study is to assess the quality and effectiveness of current university assessment system in a post-graduate computing course. We have selected the Master of Computer Applications (MCA) programme, affiliated to Mahatma Gandhi University of Kerala, India. Questions are the essential component of assessment and effective questions are the keys to productive discussion that requires students engage in higher order thinking [7]. Hence, questions have been collected from the university question papers of the past five academic years - 2009, 2010, 2011, 2012 and 2013. It has been done for the first, second and third year of the MCA programme, from the university library to form the sample for the study. Questions from the various subjects of the MCA – Structured Programming in C, Data Base Management Systems, Data Structures, Operating Systems, Java and Web Programming, Software Engineering, Data mining and Warehousing, Linux Internals and Computer Graphics - were analysed using Bloom’s taxonomy by focusing the cognitive level of the questions.

For I MCA, questions are collected from the subjects - Structured Programming in C, Data Structures and Operating Systems. Questions of Java and Web Programming, Software Engineering and Data Base Management Systems are collected from II MCA question papers. For III MCA, questions are collected from the subjects Data mining and warehousing, Computer Graphics and Linux Internals. Number of questions taken from various subjects is shown in the following tables.

Table1: Number of Questions for I MCA

Subjects	**No. of Questions**
Structured Programming in C	60
Data Structures	58
Operating Systems	57

Table2: Number of Questions for II MCA

Subjects	**No. of Questions**

Software Engineering	56
Data Base Management Systems	56
Java and Web Programming	58

Table3: Number of Questions for III MCA

Subjects	**No. of Questions**
Linux Internals	55
Computer Graphics	57
Data mining and warehousing	53

A sample of 510 questions from these question papers are subjected to analysis. Each of the 510 questions from these question papers was mapped to the respective cognitive domain levels of Bloom's Taxonomy, such as Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. The mapping was done based on question cues [1][3] as given in Table 4.

Table 4: Question cues for each BT Level

Knowledge	**Comprehension**	**Application**	**Analysis**	**Synthesis**	**Evaluation**
Describe Order Recall Reproduce Define Recite Record Match Name Recognise List Repeat Arrange Label Underline State	Arrange Express Identify Restate Explain Recognise Report Sort Interpret Locate Discuss Translate Classify Extrapolate Indicate	Apply Prepare Demonstrate Build Practice Use Operate Make Solve Illustrate Sketch Model Choose Schedule Measure Predict	Analyse Discriminate Contrast Experiment Diagram Test Examine Break Down Question Categorise Compare Differentiate Calculate Distinguish Criticise Separate	Design Propose Compose Construct Prepare Manage Organize Conduct Assemble Set Up Synthesise Modify Formulate Collect Plan	Appraise Evaluate Value Score Estimate Support Attack Rate Select Assess Predict Defend Argue Judge Critique

Analysis Results

As explained earlier, the questions collected are mapped to various levels based on the question cues. The count of questions based on each question cue is tabulated separately for each level. Then the number of questions in each level and its percentage were computed.

Number of questions belonging to knowledge level and the percentage of questions are shown in Table 5. This was computed separately for the first, second and third year questions.

Table 5: Number of questions in Knowledge Level

Question cues	**IMCA**	**IIMCA**	**IIIMCA**
Describe	25	13	8
Define	13	24	21
Name	4	6	6
Order	2		
Recite			
Recognise			
Label			
Recall			
Record			
List	20	24	17
Relate			
Reproduce			
Match			
Repeat			
State	4	5	1
Arrange			
Percentage	**39%**	**42%**	**32%**

The following lists some of the sample questions from the knowledge level.

1. *"State 2 clustering methods that are used?"*
2. *"List the advantages of DBMS over a file system?"*
3. *"Define functional dependency?"*
4. *"Define polymorphism?"*
5. *"State the system calls used for file access in Linux?"*

It has been observed that for the first year MCA, 39% of the questions were from knowledge level. For second year it was 42% and for the final year students (where we expect minimum) it was 32%.

The numbers of questions in the comprehension level and the percentage of questions for the first, second and third year students are shown in Table 6.

Table 6: Number of questions in Comprehension Level

Question Cues	IMCA	IIMCA	IIIMCA
Arrange			
Explain	40	49	53
Interpret	1		
Classify			
Express	3	1	
Recognise		4	
Locate			
Identify	15	5	26
Report			
Discuss	11	9	15
Indicate			
Restate			
Sort			
Translate			
Extrapolate			
Percentage	**40%**	**40%**	**57%**

The following lists some of the sample questions from the comprehension level.

1. *"Explain spatial data mining?"*
2. *"Explain how do you read the content of URL?"*
3. *"Explain Fork?"*
4. *"Discuss the architecture of data mining?"*

The observed results showed that for the first year MCA, 40% of the questions were from comprehension level. For the second year it was 40% and for the final year students where we expect a minimum it was 57%. The most frequently used keyword was "explain". Approximately 10% of the entire sample used this keyword.

Table 7 lists the numbers of questions and its percentage belonging to the application level for the first, second and third year students respectively.

Table 7: Number of questions in Application Level

Question Cues	IMCA	IIMCA	IIIMCA
Apply			
Practice			
Solve	12	4	
Choose			
Prepare			3
Use	1	1	
Illustrate	3		
Schedule			
Demonstrate			
Operate			
Sketch			

Measure			
Build			
Make			
Model			
Predict			
Percentage	**9%**	**3%**	**2%**

The following are some of the sample questions from the application level.

1. *"Illustrate the use of expr command in shell script?"*
2. *"Prepare SRS for an Automatic Teller Machine?"*
3. *"Prepare a tutorial on maintenance tools?"*
4. *"Illustrate K-means partitioning algorithm using the data set(x1=(0,2); x2=(0,0); x3=(1.5,0); x4=(5,0); x5=(5,2))?"*
5. *"Prepare a tutorial on biological data analysis?"*

It has been observed that for the first year MCA, only 9% of the questions were from application level. For the second year it was only 3% and for the final year, it was only 2%.

The number of questions belonging to the analysis level and the percentage of questions are shown in Table 8.

Table 8: Number of questions in Analysis Level

Question Cues	**IMCA**	**IIMCA**	**IIIMCA**
Analyse		5	1
Diagram		2	
Question			
Calculate	2	1	
Discriminate			
Test	2		
Categorise			
Distinguish	2		4
differentiate	9	11	9
Contrast			
Examine	1		
compare	2	1	1
criticise			
experiment			
break down			
separate			
Percentage	**10%**	**12%**	**9%**

Some of the sample questions in the analysis level are listed below:

1. *"Differentiate between pass by reference and pass by value?"*
2. *"Distinguish between verification and validation?"*
3. *"Compare the merits and demerits of various software process methods?"*
4. *"Compare Linux and Unix?"*

5. *"Differentiate embedded and dynamic SQL?"*

The observed results showed that for the first year MCA, only 10% of the questions were from the analysis level. For the second year it was 12% and for the final year students (where we expect maximum) it was only 9%.

Table 9 shows the number of questions and its percentage belonging to the synthesis level for the first, second and third year.

Table 9: Number of questions in Synthesis Level

Question Cues	IMCA	IIMCA	IIIMCA
design	1	1	
prepare		1	
assemble			
formulate			
propose			
manage			
set up			
collect			
compose			
organize			
synthesise			
plan			
construct	2	3	
conduct			
modify			
Percentage	**2%**	**3%**	**0%**

The following are some of the sample questions from the synthesis level.

1. *"Design an algorithm to reverse the words in a string and then change the case of every first letter of all the words?"*
2. *"Construct a class diagram for Library management system?"*
3. *"Prepare the items that need to be kept together in order to increase profit for a super market (given the transaction set)?"*

The observed results show that only few questions are mapped to the synthesis level. There were only 2% of the questions for the first year MCA and 3% of the questions for the second year. There was no synthesis question for the third year.

Surprisingly, there are no questions from the evaluation level for the first, second and third year MCA programme.

In order to compare the values, the above results are grouped based on the year and converted into bar charts. The different cognitive levels are given on the x-axis and the percentage of questions on the y-axis. It has been observed from the chart for the first year MCA that most of the questions are from the knowledge and the comprehension levels. This is represented in Fig 2. First year students are in a stage of assimilating new information and hence cannot be expected to answer many higher cognitive level questions. However, more questions may be included to test the students' higher order cognitive skills.

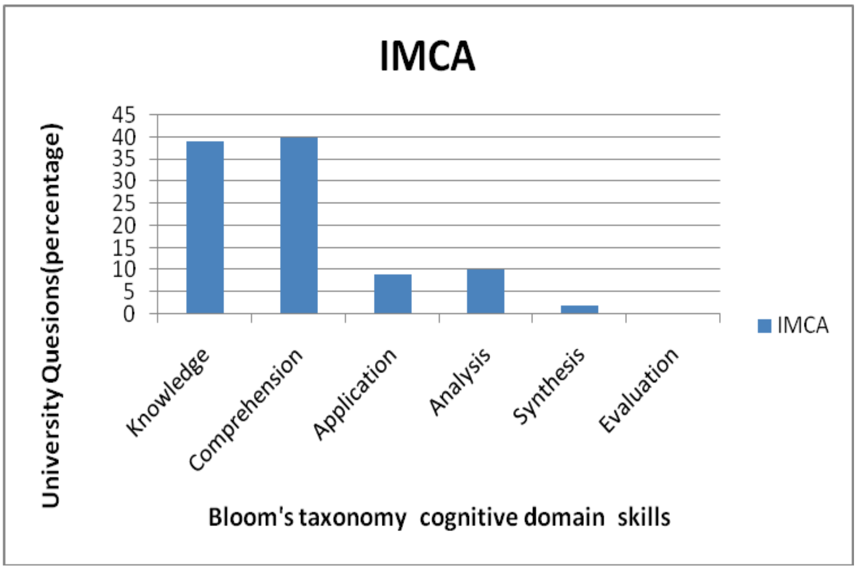

Figure 2: Mapping of I MCA questions to different cognitive levels

Figure 3 shows that, for the II year MCA students who are expected to answer more higher cognitive questions, most of the questions are mainly from the first two levels. Very few questions are included from the application, analysis and synthesis level. There are no questions from the highest level. This is really unfortunate because hardly no effort is done to test the higher order cognitive skills of the students.

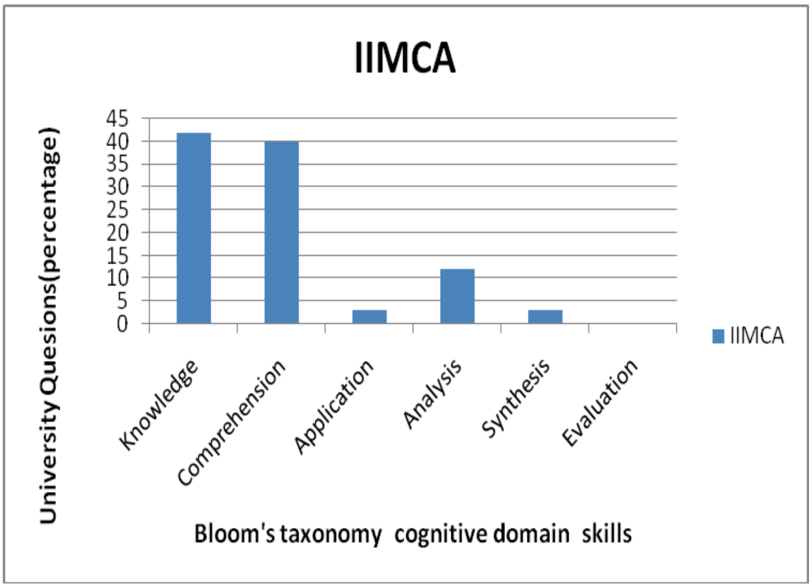

Figure3: Mapping of II MCA questions to different cognitive levels

Figure 4 shows the bar chart for the final year MCA question papers. It is observed that the highest levels such as synthesis and evaluation are not at all considered. Only the lowest levels are given importance. Thus, in the final year also their higher order cognitive skills have not been tested.

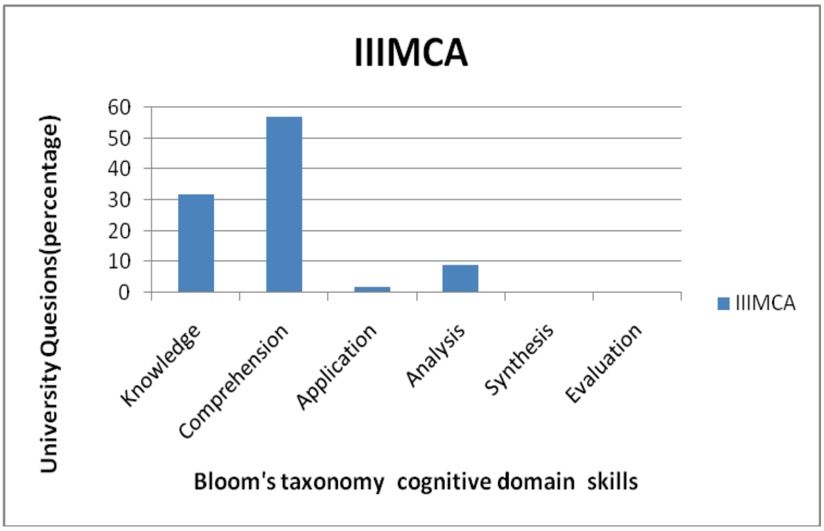

Figure 4: Mapping of III MCA questions to different cognitive levels

When all the three years' question papers are combined and analysed, it has been observed that approximately 38% of the questions are from the knowledge level, 45% of the questions are from the comprehension level, 5% of the questions are from the application level, 10% of the questions are from the analysis level and only 2% of the questions from the synthesis level. There was not even a single question to test the highest thinking skill, as shown in Fig 5.

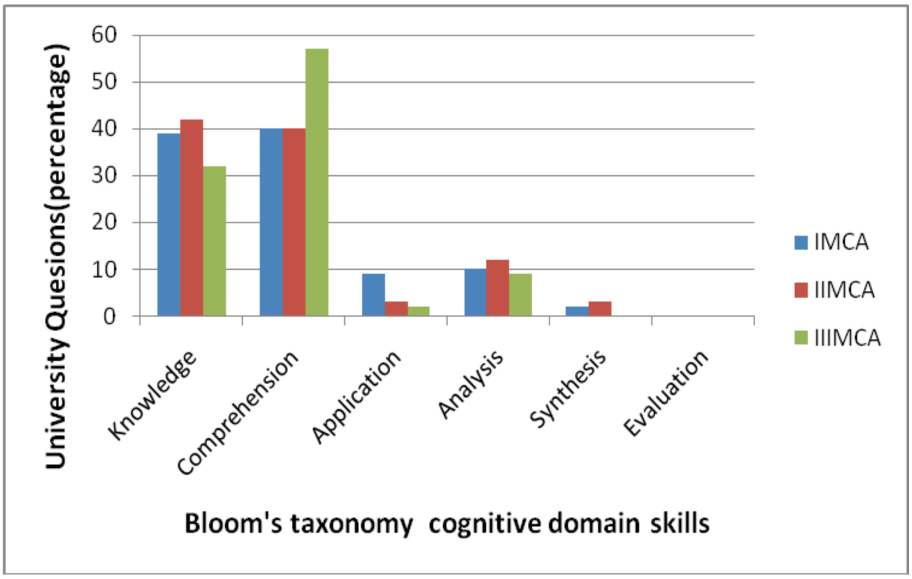

Figure 5: Mapping of questions of MCA programme to different cognitive levels

Conclusion and Future Work

The preliminary study shows that the questions from the higher cognitive levels are very less compared to the lower cognitive levels. Current assessment system has given preference to the memorization and recollection skills than the higher order thinking skills of students. This assessment pattern needs to be changed and a proper association with the Bloom's taxonomy levels are required for the improvement. In order to improve the computational thinking skills of students, teachers should ask questions which will enable the students to apply their higher order thinking skills.

It is also found that most of the teachers are interested in asking 'explain' keyed questions. A study to identify the reason for this may be useful to rectify our assessment system. This study warrants similar experiments on other computing education courses such as B.Tech, M.Tech. B.Sc., M.Sc. etc. Further research on instructional design and questions paper setting to develop and test the higher cognitive skills in students may improve the quality of computing education.

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Contact email: renumolvg@gmail.com, rekhadenny@gmail.com