ANALYTICAL STUDY ON THE USE OF BLOOM'S TAXONOMY FOR THE ASSESSMENT OF EXAM QUESTIONS IN THE PERSPECTIVE OF COMPUTER SCIENCE

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APPROVAL

This Thesis titled **"Analytical Study on the Use of Bloom's Taxonomy for the Assessment of Exam Questions in the Perspective of Computer Science"**, submitted by Raja Tariqul Hasan Tusher to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of M.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on **December 12, 2018**".

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DECLARATION

I hereby declare that, this thesis has been done by me under the supervision of **Dr. Sheak Rashed Haider Noori, Associate Professor and Associate Head, Department of Computer Science and Engineering,** Daffodil International University. I also declare that neither this thesis nor any part of this thesis has been submitted elsewhere for award of any degree or diploma.

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ABSTRACT

Bloom's taxonomy has been exploited in numerous fields of studies. It is a classification of learning objectives within education that educators set for students. The cognitive domain within this taxonomy is designed to verify a student's cognitive level during a written examination. Educators may sometimes face the challenge in analyzing whether their examination questions comply within the requirements of the Bloom's taxonomy at different cognitive levels as it is difficult to apply consistently to assessment tasks in introductory programming courses. This research paper shows the Bloom's classification categories along with keywords and question verbs those are commonly used in the exam questions in computer science and provides a consistent interpretation of some baffling keywords with concrete exemplars that will allow computer science educators to utilize Bloom's Taxonomy for programming assessment. Using Bloom's Taxonomy to help design examinations could greatly improve the quality of assessment in introductory programming courses. The main goal of this paper is to give hands on computer science and engineering teaching and learning and perk up the excellence of computer science and engineering education. In the future, this research can be further extended to automate the assessment of exam questions according to the Bloom's taxonomy of the cognitive domain.

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CHAPTER 1
INTRODUCTION

1.1 Research Objectives

Research is an organized investigation of a problem in which there is an attempt to gain solution to a problem. To get right solution of a right problem, clearly defined objectives are very important. Clearly defined objectives enlighten the way in which the researcher has to proceed. A research objective is a clear, concise, declarative statement, which provides direction to investigate the variables. Generally research objective focus on the way to measure the variables, such as to identify or describe them. Sometime objectives are directed towards identifying the relationship difference between two variables. Research objectives outline the specific goals the study plans to achieve when completed.

The research objectives are usually categorized into two categories: Overall objectives and Specific objectives.

Overall Objectives

- To study a large collection of exam question papers about the number of questions that lies in different levels of cognitive domain and compare the data in a systematic way to produce an interpretable outcomes.
- To find out the keywords and question verbs from different questions to make it easy to understand about all the levels of cognitive domain based on bloom's taxonomy.

Specific objectives

- To develop a model that will help educators to correctly measure the levels of their questions based on bloom's taxonomy.
- To develop a common pattern of keywords and question verbs of all levels of cognitive domain that will help out teachers to prepare questions according to bloom's taxonomy levels.

1.2 Motivation

Bloom's Taxonomy has been used in different subject's domain to identify the cognitive levels of questions but it has not been done to a great extent to separate the keywords of different levels in the perspective of computer science education. It is difficult to apply consistently to assessment tasks in introductory programming courses. The Bloom taxonomy is a valuable tool that could enable analysis and discussion of programming assessment if it could be interpreted consistently. In this thesis, I discuss each of the Bloom classification categories and provide a consistent interpretation with concrete exemplars that will allow computer science educators to utilize Bloom's Taxonomy for programming assessment. Using Bloom's Taxonomy to help design examinations could greatly improve the quality of assessment in introductory programming courses.

1.3 Background

Bloom's taxonomy delineates a hierarchy of cognitive-learning levels ranging from knowledge of specific facts and conventions, to more advanced levels of analysis, synthesis, and evaluation. Bloom's taxonomy is presented to help students strive to attain more sophisticated levels of understanding and abstraction in this course and their entire educational experience.

It is worthwhile discussing the concepts of levels of learning, especially as students become more comfortable with dealing with the theories of human nature and the Experiential-Learning Model, and are ready to begin to refine their work. Attention to higher level processes, such as analysis and evaluation, certainly should be integrated into written comments on draft essays and synthesis becomes very important in the development of some of the humanities papers.

1.4 Report Layout

There are six chapters in this research paper: Introduction, Bloom's Taxonomy, Literature Review, Research Methodology, Analysis & Discussion and Conclusion and Future Scope.

Chapter one, Objectives of this research, motivation behind the research, background analysis of the bloom's taxonomy that carried out to analyze the whole concept of this research.

Chapter two, Introduction to Bloom's Taxonomy; which introduced with the concept of question levelling with explaining the importance of it in the sector of assessment of the exam questions, the types of domain of the bloom's taxonomy, the cognitive domain with the description every levels; the affective domain with the description every levels and the Psychomotor domain with the description every levels

Chapter three, Literature Review; the research works which are related in the field of question assessment and other important works done by prominent researchers.

Chapter four, Research Methodology; question bank analysis to find out the common keywords, study plan to carry out the research.

Chapter five, Analysis and Discussion; comparative study of analysis section discuss about the baffling keywords in detail to give a clear view about classifying all the keywords into the different levels of the cognitive domain and a categorized table with question verbs that were very common in the analysis of the question papers.

Chapter six, Conclusion and Future Scope; the conclusion section enlighten shortly on the analysis and experiments that has been done throughout all the previous chapters, future scope are the discussion section where future possibilities and potential of this research has been highlighted.

CHAPTER 2
BLOOM'S TAXONOMY

2.1 Introduction to Bloom's Taxonomy

Benjamin Bloom was the creator of this taxonomy, as he made available his idea on the cognitive skills taxonomy in his book. Bloom was the head of a group in the 1950's and 1960's that created the classic definition of the levels of educational activity, from the very simple (like memorizing facts) to the more complex (such as analyzing or evaluating information) [1].

Bloom's taxonomy is a set of three hierarchical models used to classify educational learning objectives into levels of complexity and specificity. The three lists cover the learning objectives in cognitive, affective and sensory domains. The cognitive domain list has been the primary focus of most traditional education and is frequently used to structure curriculum learning objectives, assessments and activities.

The models Ire named after Benjamin Bloom, who chaired the committee of educators that devised the taxonomy. He also edited the first volume of the standard text, Taxonomy of Educational Objectives: The Classification of Educational Goals.

2.2 Different Domains of Bloom's Taxonomy

There are three different domains of blooms taxonomy in which cognitive domain is the most important to set exam questions according to different levels. The domains are as follows:

- The Cognitive Domain (Knowledge based)
- The Affective Domain (Emotion based)
- The Psychomotor Domain (Action based)

2.3 The Cognitive Domain

In the original version of the taxonomy, the cognitive domain is broken into the following six levels of objectives. In the 2001 revised edition of Bloom's taxonomy, the levels are slightly different:

- Remember
- Understand
- Apply
- Analyze
- Evaluate
- Create (rather than Synthesize).

Knowledge (Remembering):

Knowledge involves recognizing or remembering facts, terms, basic concepts, or answers without necessarily understanding what they mean. Its characteristics may include:

- Knowledge of specifics—terminology, specific facts
- Knowledge of ways and means of dealing with specifics—conventions, trends and sequences, classifications and categories, criteria, methodology
- Knowledge of the universals and abstractions in a field—principles and generalizations, theories and structures

Comprehension (Understanding):

Comprehension involves demonstrating understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating the main ideas.

Application:

Application involves using acquired knowledge—solving problems in new situations by applying acquired knowledge, facts, techniques and rules. Learners should be able to use prior knowledge to solve problems, identify connections and relationships and how they apply in new situations.

Analysis:

Analysis involves examining and breaking information into component parts, determining how the parts relate to one another, identifying motives or causes, making inferences, and finding evidence to support generalizations. Its characteristics include:

- Analysis of elements
- Analysis of relationships
- Analysis of organization

Synthesis:

Synthesis involves building a structure or pattern from diverse elements; it also refers to the act of putting parts together to form a whole. Its characteristics include:

- Production of a unique communication
- Production of a plan, or proposed set of operations
- Derivation of a set of abstract relations

Evaluation:

Evaluation involves presenting and defending opinions by making judgments about information, the validity of ideas, or quality of work based on a set of criteria. Its characteristics include:

- Judgments in terms of internal evidence
- Judgments in terms of external criteria

2.4 The Affective Domain

Skills in the affective domain describe the way people react emotionally and their ability to feel other living things' pain or joy. Affective objectives typically target the awareness and growth in attitudes, emotion, and feelings.

There are five levels in the affective domain moving through the lowest-order processes to the highest.

Receiving:

The lowest level; the student passively pays attention. Without this level, no learning can occur. Receiving is about the student's memory and recognition as Ill.

Responding:

The student actively participates in the learning process, not only attends to a stimulus; the student also reacts in some way.

Valuing:

The student attaches a value to an object, phenomenon, or piece of information. The student associates a value or some values to the knowledge they acquired.

Organizing:

The student can put together different values, information, and ideas, and can accommodate them within his/her own schema; the student is comparing, relating and elaborating on what has been learned.

Characterizing:

The student at this level tries to build abstract knowledge.

2.5 The Psychomotor Domain

Skills in the psychomotor domain describe the ability to physically manipulate a tool or instrument like a hand or a hammer. Psychomotor objectives usually focus on change and/or development in behavior and/or skills.

Bloom and his colleagues never created subcategories for skills in the psychomotor domain, but since then other educators have created their own psychomotor taxonomies.

Perception:

The ability to use sensory cues to guide motor activity: This ranges from sensory stimulation, through cue selection, to translation.

Set:

Readiness to act: It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine a person's response to different situations (sometimes called mindsets). This subdivision of psychomotor is closely related with the "responding to phenomena" subdivision of the affective domain.

Guided Response:

The early stages of learning a complex skill that includes imitation and trial and error: Adequacy of performance is achieved by practicing.

Mechanism:

The intermediate stage in learning a complex skill: Learned responses have become habitual and the movements can be performed with some confidence and proficiency.

Complex overt response:

The skillful performance of motor acts that involve complex movement patterns: Proficiency is indicated by a quick, accurate, and highly coordinated performance, requiring a minimum of energy. This category includes performing without hesitation and automatic performance. For example, players will often utter sounds of satisfaction or expletives as soon as they hit a tennis ball or throw a football because they can tell by the feel of the act what the result will produce.

Adaptation:

Skills are Ill developed and the individual can modify movement patterns to fit special requirements.

Origination:

Creating new movement patterns to fit a particular situation or specific problem: Learning outcomes emphasize creativity based upon highly developed skills [12].

CHAPTER 3
LITERATURE REVIEW

Bloom’s taxonomy was devised in the 1950s as a generic instrument for dividing the cognitive aspects of learning into hierarchical levels. It is now widely used in course design in higher education, as a way of ensuring that teaching and assessment strike the right balance between rote learning of content and high level skills such as synthesis and evaluation. The application of these cognitive levels now goes far beyond the design of individual modules.

A departmental attempt to improve assessment led the authors of this paper to apply Bloom’s taxonomy to a number of first year modules and to wonder whether the ordering in its hierarchy is appropriate for computer science. This paper outlines our study of practice in a single university, and throws the question of the aptness of Bloom to computer science open to wider debate [3].

The computer science education literature contains a small number of examples of the use of a taxonomy as an analytic tool. Bloom’s taxonomy has been applied in course design; for example Scott [9] and Lister & Leaney [6] have used it for structuring assessments.

Bloom et al Ire somewhat equivocal about whether evaluation should be above or on the same level as synthesis and they Ire also not dogmatic about whether evidence of performance at a higher level necessarily demonstrated performance at all the lower levels.

There appear to be many interpretations of this taxonomy. Some teachers see the hierarchy as applying to individual topics. Every topic is capable of being approached at each of the levels, and the more successful the student is the higher the level she or he will reach. An alternative idea is that the hierarchy represents progress through the subject as a whole, for example in a degree program. Under this interpretation, the lower levels correspond to early years of study, with the final aim of the program being that all students will be enabled to achieve at the highest level.
Recent re-evaluation of Bloom’s taxonomy by Anderson, Krathwohl et al [5] has suggested that the top two or three levels of the hierarchy may be flat (Figure 1). They have also proposed that the taxonomy should be two dimensional, with the (slightly reconfigured) original categories of

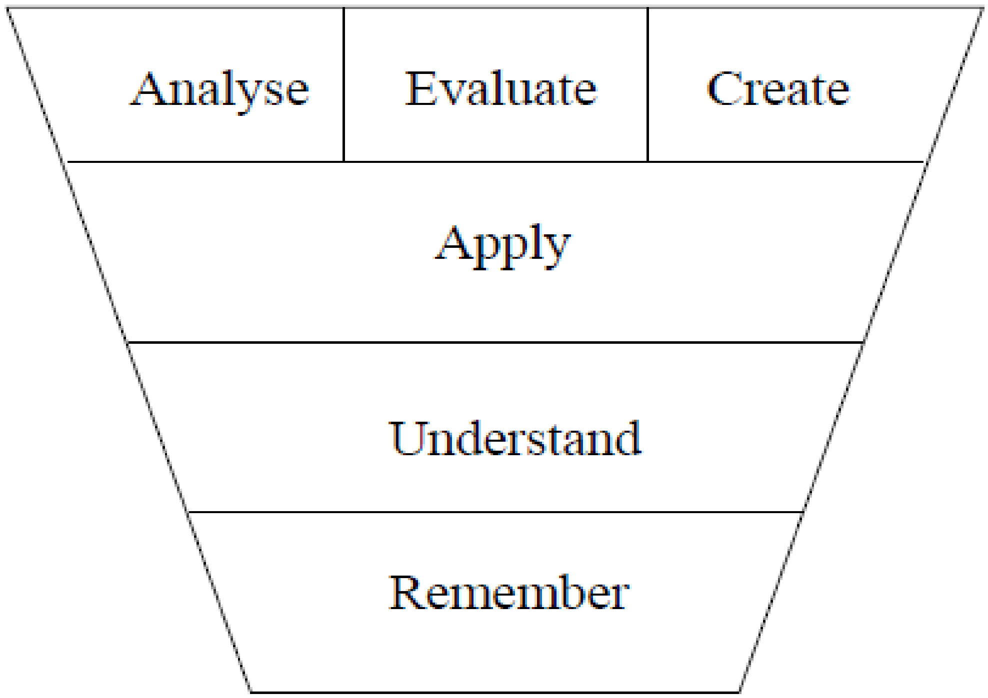

Figure 3.1: Bloom's Taxonomy 'flattened'

Remember, Understand, Apply, Analyze, and Evaluate and Create forming the cognitive process dimension and Factual, Conceptual, Procedural and Meta-Cognitive forming a knowledge dimension.

Whilst Bloom's taxonomy of the cognitive domain has the widest currency, it is not the only such taxonomy. For example, Bloom and his colleagues produced a much less Ill known taxonomy of the affective domain, while Biggs' SOLO taxonomy [8] charts increasing structural complexity in student learning outcomes. This identifies that learning first changes quantitatively, as the amount of detail in the students response increases, and then qualitatively, as the detail becomes integrated into a structural pattern. The computer science education literature contains a small number of examples of the use of a taxonomy as an analytic tool. Bloom's taxonomy has been applied in course design; for example Scott [15] and Lister & Leaney [13] have used it for structuring assessments.

A significant feature of a study of Johnson [7] assessment in computer science modules was that the focus of assessment appeared to be at the application level. That might hypothesize that in disciplines such as computing the aim of study is what I might term 'higher application'. Here they used the word higher in the sense that is used in terms such as 'higher criticism' or 'higher journalism' i.e. the application informed by a critical approach to the subject, but where the criticism is not, as such, the focus of the work. In such work, the focus is at the application level in Bloom's taxonomy yet this needs to be informed both by levels that Bloom puts below and above. This is illustrated in Figure 2, which contrasts with Figure 1 by adding a higher application capstone level.

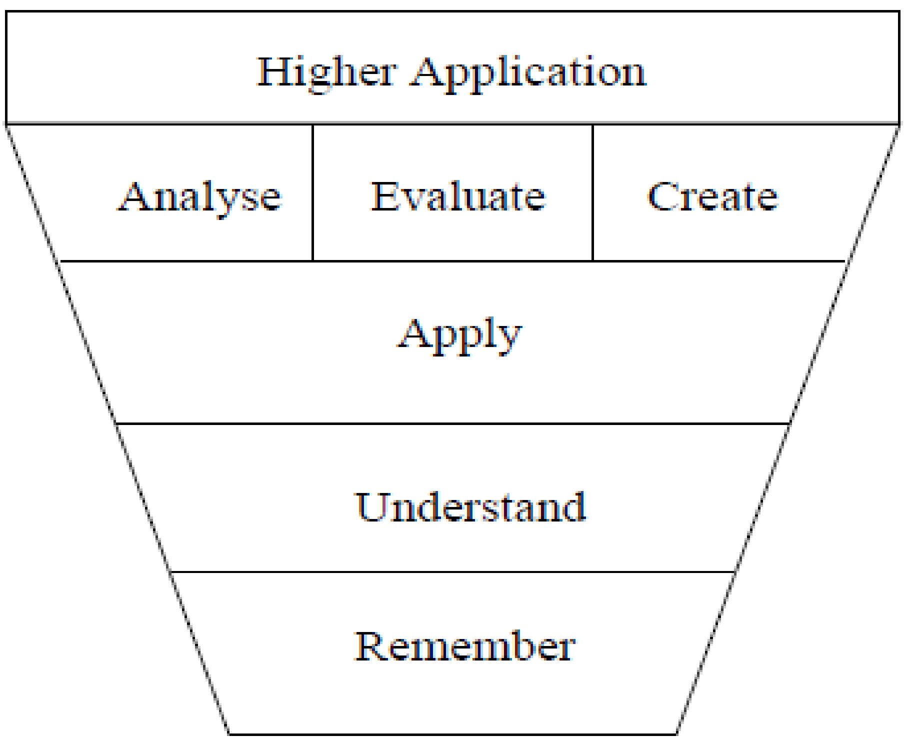

Figure 3.2: A suggested revised Bloom taxonomy for computing, incorporating higher application.

In the research of Salmah [17] they focused on the Multimedia subject taught in Computer Science discipline. In view of the fact that every subject has its own quality, the keywords categories proposed by Bloom cannot be completely adopted in Multimedia subject. For that reason, all the listed keywords in Bloom's taxonomy must be examined and adjusted to suite Multimedia subject. That exercise facilitated by the Multimedia and Bloom Taxonomy experts. The experts will study the Multimedia sample questions, extracting the keywords and re-categorize them to six difficulty levels as proposed by Bloom. Based on the outcomes, a database consisting of keywords, arranged according to the six difficulty levels developed. Besides extracting and re-categorizing the keywords, rules/guidelines to design a good examination question paper will also be developed by the experts. That research aims to develop a system, which is able to find keyword/s in the new draft question, compare it with the keyword stored in the database and specify the difficulty level of the question. This process is applied to every question in the draft examination question paper. The outcomes then, used by the system to make overall conclusion on the drafted examination question paper. Figure 3 explains the flow of the system development.

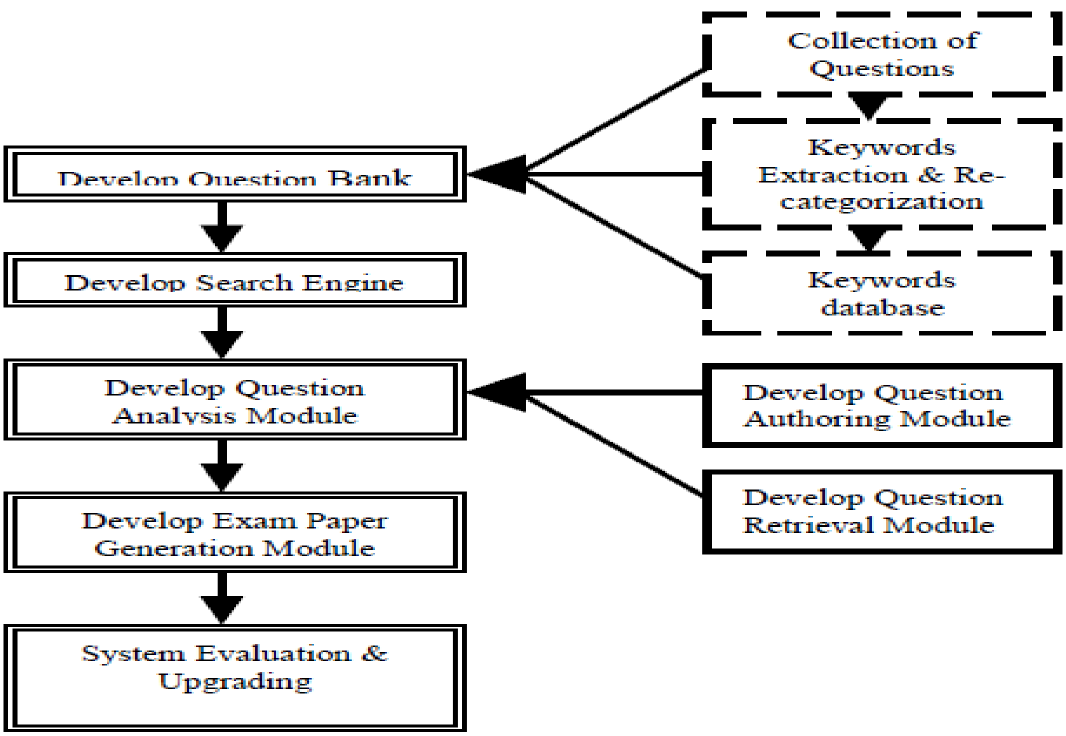

Figure 3.3: The System Development Flow

Bloom’s Taxonomy was applied on three computer science courses by Machanick [2]. His experience was then analyzed and he decided that Bloom’s Taxonomy-based approach works healthy Software engineering is an element of computer science. Several research have been seen in many of computer science field of studies including computer science itself being associated to Bloom’s Taxonomy. From live research, Bloom’s Taxonomy seems to be extremely helpful for education purposes and is still much admired after more than 5 decades. It has been extensively used for learning objectives measurement and assessment.

CHAPTER 4
RESEARCH METHODOLOGY

The goal of this thesis is to give a clear view of the use of bloom's taxonomy in the exam questions and to analyze the exam question according to bloom's taxonomy of the cognitive domain to provide effective recommendations. To successfully conduct the thesis below steps were taken.

- A study on revised bloom's taxonomy of the cognitive domain.
- The uses of different levels of bloom's classification in exam questions.
- Revised models of cognitive domain for computer science.
- Various papers on bloom's taxonomy.
- To get the complete idea about the keywords 95 sets of question papers of computer science of our department has been analyzed.
- Various papers and books on survey methods are studied.
- The questions relevant to those facts are identified.
- Desired question verbs are divided into different categories.
- Based on the keywords and question verbs (found from the analyzed question papers) relevant keywords are classified according to cognitive domain.
- Finally, a complete set of keywords, question verbs and detail discussion of some baffling keywords are proposed to understand the use of bloom's in the assessment of exam questions.

For this study, exam scripts of previous semesters from first-year to final-year computer courses are collected from our department supplied. The questions in the exams varied in nature and included true or false, multiple-choice, short and long answer questions. Each exam script was independently analyzed by me, and its questions classified according to the revised Bloom's taxonomy. The exams are all written final exams, and each individual question was classified in both the cognitive and knowledge dimensions.

Following this first classification phase the differences in the way that each academic applied the taxonomy are noted and discussed in detail in order to determine the cause of the discrepancy and to come to a common understanding.

Initially I discovered significant differences between the categories that I had assigned to many questions. This was primarily due to difficulty mapping the cognitive tasks described by the taxonomy's authors into the programming domain, for which there are no examples.

In some cases, differences in categorization Ire due to an academic being involved with a course and therefore able to provide the teaching context for the assessment task in question. Once the teaching context was elucidated, I was able to agree on an appropriate cognitive category for the assessment task in question.

The following question provides an example of this process.

Given the following class:

```
public class Circle
{
        private int diameter;
        private int xPosition;
        private int yPosition;
        private String color;
        private boolean isVisible;
        public Circle()
      {
          diameter = 30;
          xPosition = 20;
          yPosition = 60;
          color = “blue”;
          isVisible = false;
      }
//code removed for briefness
}
```

Write a constructor that would allow the location, colour, and diameter of the circle to be set. Show how this constructor would be used to create a circle at x = 200 and y = 400, with colour blue, and diameter = 90.

The teachers who are not involved in the teaching of the course can categorise this question either as Understand (on the basis that this question required students to provide an example of a familiar concept), or Create (on the basis that it asked students to combine code in a way that they had not seen before).

The person who had the course classified the question as Apply. The course material explicitly taught a process for writing constructors that accepted parameters. The lecturer of the course may felt that this question asked students to apply a known process to a familiar situation (i.e. the students had been taught a process for handling this sort of question and had seen similar examples, but had not seen this particular code).

Once the teaching context had been explained, the authors agreed unanimously that Apply was the appropriate classification in this case. I concluded that in order to effectively analyse a question the person undertaking the analysis should have an in-depth knowledge of the course as a whole. This belief is also supported by Johnson and Fuller [3].

Using the analysis as a talking and reference point, I tried to develop an agreed understanding of the Bloom categories and subcategories and to develop new descriptors.

CHAPTER 5
ANALYSIS & DISCUSSION

5.1 Classification of keywords and question verbs

According to the analysis of 95 sets of exam question papers of computer science I have classified the keywords and question verbs those are commonly used in the questions of our department. Here table 1 shows the classification of different levels of the cognitive domain of bloom's taxonomy.

Table 5.1: summarization each levels of Bloom's taxonomy from analysis

Revised Bloom's Category	Definition	Common Keywords	Sample Question Verbs
Remembering	can the student recall or remember the information?	arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, write, state, repeat.	Define, , state, identify, label, name, list who? when? where? what?
Understanding	can the student explain ideas or concepts?	classify, describe, discuss, explain, draw, express, identify, indicate, locate, recognize, report, restate, review, select, translate,	Explain, predict, interpret, infer, summarize, convert, translate, give example,
Applying	can the student use the information in a new way?	apply, choose, operate demonstrate, employ, illustrate, interpret, schedule, sketch, solve, use, write.	How could x be used to y? How would you show, make use of, modify, demonstrate, solve, or apply x to conditions y?
Analyzing	can the student distinguish between the different parts?	analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate,	Differentiate, compare / contrast, distinguish x from y, how does x affect or relate to y? why?

		discriminate, distinguish, examine, experiment, question, test.	how? What piece of x is missing / needed?
Evaluating	can the student justify a stand or decision?	appraise, argue, assess, attach, choose, compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate.	Justify, appraise, evaluate, judge x according to given criteria. Which option would be better /preferable to party y?
Creating	can the student create new product or point of view?	arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, write.	appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate.

5.2 Discussion of Cognitive Categories with some baffling keywords

Anderson et al. (2001) provide vignettes of how the knowledge and cognitive categories apply in a number of different subject area domains [10]. Computer science and programming are not among the subject areas covered. Here I endeavor to describe the categories using examples specific to programming.

One of the difficulties with using the cognitive hierarchy in a programming context is clarifying what it means to apply a process and/or to create a process. For the purposes of this paper, the following distinction is made.

Process: This is the procedure that a person might learn or create in order to be able to write a code segment. Examples of processes are code tracing, desk checking, translation from design to code, and implementing a known algorithm. In terms of the knowledge dimensions of the taxonomy this is process knowledge.

Algorithm: This is used in the computer science sense as a portion of program code or a code pattern designed to achieve a particular task within a program. From an object-oriented perspective, a design pattern would be the equivalent of an algorithm. This is also regarded as process knowledge within the taxonomy [10].

Remember

Remember is defined as 'retrieving relevant knowledge from long-term memory' (Anderson et al. 2001). In the revised taxonomy, this category includes recognizing and recalling. I interpret this in programming assessment terms to mean:

1. identifying a particular construct in a piece of code;
2. recognizing the implementation of a subject area concept;
3. recognizing the appropriate description for a subject area concept or term;
4. recalling any material explicitly covered in the teaching program. This might be factual knowledge, the recall of a conceptual definition, the recall of a process, the recall of an algorithm, the recall of a design pattern, or the recall of a particular algorithm or design pattern implemented as a solution to a specific problem in exactly the same context as a classroom based exercise.

Examples

a) List the arithmetic operators in increasing order of precedence.

b) Define the purpose of a constructor.

c) Describe the state pattern.

Discussion

In these instances students are asked to perform tasks requiring knowledge that they could have rote-learned. The use of verbs such as list and describe are regarded as synonyms for recall. In the second example above, the task would belong to the Remember category if the course materials included a definition of the purpose of a constructor (for example, on an overhead slide).

Determining if a task belongs to this category often requires detailed knowledge of the course materials, since the most significant factor for this category is whether the student has seen the solution to the task before. If the task can be completed simply by remembering something, the assessment task belongs to this category; otherwise it must belong to one of the following 5 categories.

Understand

Understand is defined as ‘constructing meaning from instructional messages, including oral, written, and graphical communications’. In the revised taxonomy, this category includes Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing, and Explaining. I interpret this in programming assessment terms to mean:

1. translating an algorithm from one form of representation to another form;
2. explaining a concept or an algorithm or design pattern;
3. presenting an example of concept or an algorithm or design pattern.

Example one

Look at this section of code and explain in plain English what it does.

```
public static int mystery(int[] x, int a, int b)
{
    int z = 0;
    for (int i = a; i <=b; i++)
    {
        z = z + x[i];
    }
    return (z / (b-a+1));
}
```

Discussion

The students are provided with a segment of code and asked to explain what the code does. Explain is one of the subcategories of the Understand category.

Apply

Apply is defined as 'carrying out or using a procedure in a given situation'. In the revised taxonomy, this category includes Executing and Implementing. I interpret this in programming terms to mean:

1. that the process and algorithm or design pattern is known to the learner and both are applied to a problem that is familiar, but that has not been solved previously in the same context or with the same data or with the same tools; or
2. that the process and algorithm or design pattern is known to the learner, and both are applied to an unfamiliar problem

Example one

Evaluate the expression: 2 + 4 / 7 * 5 % 3 == 7

Discussion

This example requires a student to follow a known process and to apply the rules of precedence in order to evaluate the expression shown. If the expression was extremely simple, such as "1 + 2", then I would expect the student to evaluate the expression using recall, so the **Remember** category would be most appropriate. In this less simple case, the complexity of the expression requires students to follow an algorithm in order to compute the results. The process requires students to understand the rules dictating the order of precedence and evaluate the expression by performing the operations in the correct order. The critical part of the question that results in the **Apply** categorization is that students are applying a process in order to solve the problem (in this case, applying a known process to a familiar problem, although with unfamiliar data).

Although the word "Evaluate" is used in this question, the meaning is not the same as the meaning of the cognitive process category **Evaluate** which is "making judgments based on criteria and standards" (Anderson et al. 2001). This isn't what the students are being asked to do in this example. "Evaluate" in this context means to apply the process for expression evaluation to determine the end result of using the given expression. This example is therefore in the **Apply** cognitive process category.

Analyse

Analyse is defined as 'breaking material into its constituent parts and determining how the parts relate to one another and to an overall structure or purpose'. In the revised taxonomy, this category includes Differentiating, Organising, and Attributing. I interpret this in programming assessment terms to mean:

1. breaking a programming task into its component parts (classes, components, etc.);
2. organising component parts to achieve an overall objective;
3. identifying critical components of a development;
4. identifying unimportant components or requirements.

Example

Given the code for a Circle class, the students are asked:

a) What is the method Circle in this class?

b) How does it differ from other methods in the class?

Discussion

In the example above, students Ire expected to provide answers such as a) "It's a constructor", and b) "It is invoked when a new objected is created". This is the reverse of the question used as example two for the **Understand** category. Given the name of the method, the students have to identify what type of method it is, and then identify the difference between it and other methods.

The first part of the question (what is) involves recalling that a method with the same name as the class is a constructor, and concluding that the named method is therefore a constructor. In the second half of the question (how does) the students are being asked to differentiate between a constructor and other methods of the class. Differentiating is one of the subcategories of the **Analyse** cognitive process category.

Evaluate

Evaluate is defined as 'making judgments based on criteria and standards'. In the revised taxonomy, this category includes Checking and Critiquing. I interpret this in programming assessment terms to mean:

1. determining whether a piece of code satisfies the requirements through defining an appropriate testing strategy;
2. critiquing the quality of a piece of code based on coding standards or performance criteria.

Example

The students have been given a class that has the following declaration.

```
private double numbers[] = new double[10];
private int used = 0;
```

In that class, there is an existing method that calculates the minimum using the following for loop.

```
for (int i = 0; i < used; i++) {
   min = Math.min(min, numbers[i]);
```

The question reads:

It has been proposed that a better solution for the min method would be

```
public double min() {
     double min = numbers[0];
     for (double number : numbers) {
        min = Math.min(min, number);
     }
     return min;
}
```

Discuss the differences between these solutions using the current collection type of the *numbers* variable and discuss which method is more appropriate for the current collection type.

Discussion

Discussing the differences involves comparing the two loop constructs and contrasting their usage. This belongs in the **Understand** category. The students are asked to go further and to discuss which method is more appropriate. This involves evaluating the use of two different loop constructs that are used for the same purpose. The second option fails because all cells in the array will be used in finding the minimum even if some of the cells of the array have not been given values. The students must use this knowledge to evaluate the preferred loop construct for the given collection type. This question is therefore in the **Evaluate** cognitive process category.

Create

Create is defined as 'putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure'. In the revised taxonomy, this category includes Generating, Planning, and Producing. I interpret this in programming assessment terms to mean:

1. coming up with a new alternative algorithm or hypothesizing that a new combination of algorithms will solve a problem;
2. devising an alternative process or strategy for solving a problem; or complex programming tasks, this might include dividing the task into smaller chunks to which they can apply known algorithms and processes;
3. constructing a code segment or program either from an invented algorithm or through the application of known algorithms in a combination that is new to the students.

Example

Write a method get24HourTime () which accepts three parameters and returns a String. The three parameters are an int representing the hour value, an int representing the minute value and a String which is either "am" or "pm". The method returns a String representing the time as a 24-hour time value. For example, 2:35pm is "14:35" in 24-hour time.

Note: 12:0pm is "12:0" in 24-hour time and 12.0am is "0:0" in 24-hour time.

For example, executing the Q4 program with the completed get24HourTime() method produces the following output:

```
> java Q4App
20:23
```

12:0

0:0

7:15

Discussion

The difficulty with questions of this type is to determine whether they are **Apply** or **Create**. The size of the problem does influence the difficulty of the problem, but it doesn't determine whether it is **Apply** or **Create**. The Create category should require creative thinking and the formation of a "coherent or functional whole" [10]. If the students are familiar with the algorithm and process then the cognitive load is loIr and therefore the question should be categorised as **Apply**. To answer this type of question, the students should be familiar with the process for designing an algorithm.

The cognitive category of **Create** applies where the student has no familiarity with completed functional whole. While they haven't seen the algorithm before, they might have seen background material or bits and pieces, but not the completed whole.

The cognitive category of **Apply** requires knowledge of an algorithm and/or process and its application to a given situation. In programming terms this is where students have seen the same or a very similar algorithm working with different data or presented in a different implementation language.

The cognitive category of **Remember** could apply to this type of question if the students had already seen the exact problem solution in the same language, algorithm and process. That is, they have seen the exact same thing in the same context.

In a large program there may be parts that are Apply (i.e. applying a design pattern) but the whole could be Create since there may be a need to use novel strategies and coding as a link between the component parts.

With this example, the question was therefore categorized as **Create**.

5.4 Summary

The proposed Bloom's taxonomy forced us to review the exam questions in terms of how the paper/subject was taught. Simply reading the questions did not always give a clear indication of the cognitive skill involved in addressing the question. For example, some questions requiring students to recall something covered in class would be extremely easy (such as "What language do I use to program in this course?"), while others would be extremely difficult (such as "What is the 3rd word that appears on slide 3 of the second lecture?"). It should also be recognized that the actual cognitive process that is applied to a specific task will depend on the individual solving that task. A given task might require nothing more than recall (the lowest level of cognitive process) for one individual, but may require another individual to generate a new solution to a situation that they find novel (using the highest level of cognitive process). The context is critical for assessing members.

CHAPTER 6
CONCLUSION & FUTURE WORK

Conclusion

I have presented the application of Bloom's taxonomy in computer engineering education. This will assist educators in crafting their questions for computer engineering assessments, given the level of question types. It will be helpful for assessment and ensuring that computer engineering students' knowledge level and skills acquired are as defined by the learning outcomes.

Future Work

In my experiments, related to most work in the literature, each level of cognitive domain is classified with common keywords and question verbs that we actually use while generating the questions. By using this common keywords and question verbs and baffling keywords idea I want to automate the analysis of the exam questions using natural language processing.

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