Model Development Of A Recommender System For Cognitive Domain Assessment Based On Bloom's Taxonomies

Raphael Banda, Jackson Phiri, Mayumbo Nyirenda

Abstract— Assessment in education is an instance of making a judgment whether learning has taken place in the students. In assessing students scholars use verbs such as *count, create, summarise or evaluate*. These verbs found in standard questions to assess students or candidates in a test or examination are drawn from Bloom's Taxonomies of the *Cognitive Domain* and are called *action verbs*. The cognitive domain has six levels; *Remembering, Understanding, Applying, Analysing, Evaluating* and *Creating*. These six levels of the Cognitive are used to classify educational learning objectives into levels of complexity and specificity. An action verb in a particular test item can belong to any of the six levels of the cognitive domain. A survey was carried out and the findings were that the use of the Cognitive Domain levels in setting test items is not common in awarding marks to questions. Awarding of marks to questions is done at random without considering the levels where such action verbs are drawn from. A recommender system has been developed that analyses the questions and recommends marks to be awarded according to the weights of such action verbs used. It can also analyse syllabi content and make a judgement as to whether the curriculum tests low level competences or high-level competences. Analysis of questions is based on the cognitive domain as it is the most common domain used in schools and universities. Analysis of questions can improve the way students are assessed. To develop the system a model was designed and Web technologies was used. For programming purposes *PHP* and *MySQL* was used. *MySQL* was used to design the databases for the action verbs. These were systematically arranged in the databases for ease of manipulation and retrieval. *WAMP Server* is compatible with other programming languages such as JavaScript and *HTML*. This makes the system is scalable on the internet.

Index Terms— Action verb, Bloom's Taxonomy, Cognitive Domain, PHP, Wamp Server, Weight, Web Technology.

I. INTRODUCTION

Assessment in education is done to test competences that the learners have acquired [1]. Assessments are used to award marks to assess students competences or for promotion purposes to another grade or level. However most of the testing or assessment tools or test items that are used lack scientific backing or justification. They are done in a hit-or-miss manner such that most people question their credibility as they lack scientific backing or justification [1]. Students at the same level of achievements are given similar tests to assess their competences in that subject. In trying to make the results of similar tests some scholars have used the Jaccard coefficient for keywords [1]. This technique uses key words from text to award weights to such words. This technique can also help in awarding the necessary or justified marks to the questions depending on the frequency of such words. Technically, [2, 1] developed a measure of similarity Jaccard with Prolog programming language to compare similarity between sets of data. Blooms Taxonomies action verbs are classified and are given levels depending on the verb where such verbs are found. This makes work a bit easier since action verbs are technically awarded marks even before they are used in constructing questions for the students. Every investigation begins with ideas that are further developed and inspired to address a variety of situations and circumstances [3]. Research is also a systematic effort to get answers to a certain problem [4].There is a need to systematically set examinations or test items following the well-known and practiced action verbs of the Bloom's Taxonomies. Most of the lecturers and teachers alike set such questions with little or no knowledge of the implication of the questions that they set on their students or learners. Security of such examinations can also be of a challenge as questions set may be tampered with by hackers and other people who are not be allowed to have access to such questions.

An evaluation into examinations questions carried out indicated that curriculums at both school level and university level did not test higher levels of the cognitive domain of Bloom's taxonomies. This has resulted in many exams set to either underscore the marks for a given question or over score depending on the action verbs used. As a result the validity of such examinations can be questionable. The study was aimed at finding ways of assisting educators in the education system or academia to correctly develop items that can have meaning to their assessment. The study proposes the use of a model that would add value to the examinations items set by the educators. There are a lot of educators who have not heard of how questions can be set in order to test different levels of the learners/ students competences. We have seen questions of less value being given more marks than those that deserve more marks [1]. For example when we consider the following questions taken from past examinations papers do they really deserve the marks that they were given.

Example questions:

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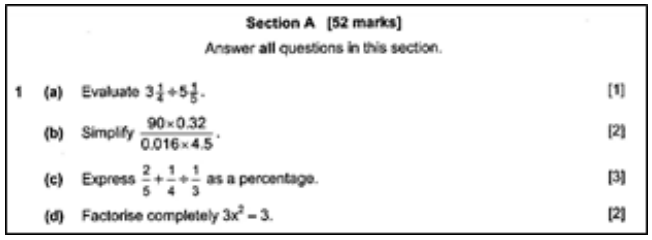


Section A [52 marks]

Answer **all** questions in this section.

1 (a) Evaluate $3\frac{1}{4} \div 5\frac{1}{5}$. [1]

(b) Simplify $\frac{90 \times 0.32}{0.016 \times 4.5}$. [2]

(c) Express $\frac{2}{5} + \frac{1}{4} \div \frac{1}{3}$ as a percentage. [3]

(d) Factorise completely $3x^2 - 3$. [2]

Fig. 1. Mathematics Paper 2 exam paper (Source: Examinations Council of Zambia - 2011) [1]

We noted that the question in *Fig. 1* has action verbs: *evaluate, simplify, express, factorise* coming from different levels of the cognitive domains. Evaluate (level 5 of Cognitive Domain), simplify (level 3 of Cognitive Domain), express (level 2 of Cognitive Domain), and factorise (level 2 of Cognitive Domain). We note that express is in level 2 and yet it is given more marks than evaluate that is in level 5 of the cognitive domain. This indicates that there is a problem in the way we construct questions and award marks to the question that we set.

II. Related Works

2.1 Review of the Leaving Certificate biology examination papers (1999– 2008) using Bloom's taxonomy – an investigation of the cognitive demands of the examination

In this study past examination papers and current biology syllabuses analysed. Analysis was also carried out to determine the marks being awarded to the different cognitive objectives [9]. Their findings show that the examination predominately includes questions that do not promote higher levels of thinking.

Blooms taxonomies of the cognitive domain can be divided into two segments of levels; the higher level and the lower level of the cognitive domain. ***Knowledge, comprehension*** and ***Application*** are at lower levels whilst ***analysis, synthesis*** and ***evaluation*** are at higher levels. This means that questions at lower levels are supposed to have lower marks than those at higher levels.

The researchers used the Bloom's Taxonomy of educational objectives – cognitive domain (1956) as the theoretical framework for the analysis [9]. Bloom's Taxonomy of educational objectives is arguably one of the most influential educational monographs of the past half a century [9]. The cognitive domain is divided into the following objectives: knowledge, comprehension, application, analysis, synthesis and evaluation , in which knowledge is the lowest form of cognitive thinking and evaluation is the highest [9]. This is shown in the Fig. 2.

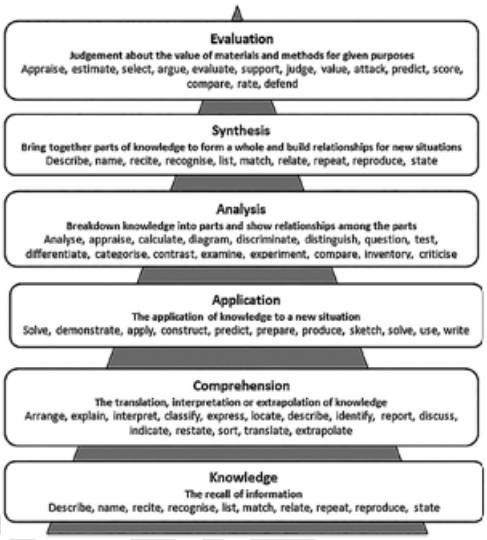
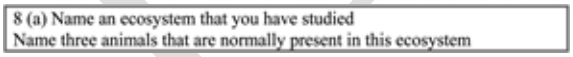


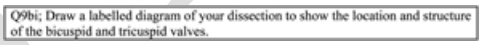
Fig 2. Bloom's taxonomy of educational objectives: cognitive domain (1956) with associated verbs [5, 1]

Researchers gave some examples on how they awarded the marks to each question analysed. Figs 3 and 4 show some of the questions that they analysed were analysed.



8 (a) Name an ecosystem that you have studied
Name three animals that are normally present in this ecosystem

Fig. 3. Example of a **knowledge**-type question from the 2004 Leaving Certificate biology honours level, Q8a. [5, 1]



Q9bi; Draw a labelled diagram of your dissection to show the location and structure of the bicuspid and tricuspid valves.

Fig 4. Example of an **application**-type question from the 2004 honours-level biology paper, Q9bi. [5, 1]

Tables 1 and 2 illustrate the results of the research across the years drawn from the *Cognitive Domain.*

TABLE 1.
FREQUENCY OF MARKS PER COGNITIVE OBJECTIVE IN CURRENT CURRICULUM FOR THE HIGHER LEVEL LEAVING CERTIFICATE BIOLOGY PAPER. [1]

	2004	2005	2006	2007	2008	Average
Knowledge	51.74%	58.81%	62.2%	55.05%	49.05%	55.37%
Comprehension	29.91%	29.52%	25.19%	30.13%	23.66%	27.46%
Application	12.66%	8.25%	3.70%	7.10%	13.38%	9.12%
Analysis	5.06%	8.41%	7.41%	7.75%	13.41%	8.40%
Synthesis	1.42%	0.00%	0.74%	0.00%	0.00%	0.43%
Evaluation	0.32%	0.00%	0.74%	0.00%	0.00%	0.21%

TABLE 2
FREQUENCY OF MARKS PER COGNITIVE OBJECTIVE IN CURRENT CURRICULUM FOR THE ORDINARY-LEVEL BIOLOGY PAPER [1]

	2004	2005	2006	2007	2008	Average
Knowledge	66.7%	74.88%	70.30%	82.99%	72.39%	73.45%
Comprehension	29.91%	16.59%	16.75%	12.76%	19.08%	19.02%
Application	1.90%	7.11%	5.06%	4.25%	9.18%	4.90%
Analysis	1.42%	0.00%	6.48%	0.00%	2.37%	2.05%
Synthesis	0.00%	1.42%	0.00%	0.00%	0.00%	0.28%
Evaluation	0.00%	0.00%	1.42%	0.00%	0.00%	0.28%

Results in the tables above indicate that there were more marks on the paper allocated to the lower objectives of the taxonomy, suggesting students can rely on rote learning to succeed when undertaking the biology examination [9]. This study strongly highlights how high-stake examinations have a narrow scope in terms of student achievement and shows how current biology examination procedures promote low-level learning. This low level of thinking promotes rote

learning and regurgitation of facts, requiring little to no understanding of the topics [9].

2.2 Blooms Taxonomy– Application in Exam Papers Assessment

[10] explored the elements of Blooms Taxonomy in examination assessment system at Caledonian College of Engineering, Sultanate of Oman. They studied the methodology adopted by the assessment office of the College, in testing the students' cognition levels (applying Blooms Taxonomy principles) and the questions for [10].

In this study S. I. Sivaraman and D. Krishna they said that that the Caledonian College of Engineering applied Blooms Taxonomy in assessment systems for the following reasons in addition to the mapping of the cognitive levels [10]:

1. The system makes the teaching staff to think about the type of questions before they are put in black and white.
2. This brings about a clarity when questions are formulated by the staff members.
3. It is possible that the question paper is termed as tough or easy by the students. Blooms Taxonomy assists the staff to bring out a balance while setting the question paper.
4. Consistency is also observed across all module question papers when Blooms taxonomy is introduced in the assessment system.
5.

The following table depicts the teams concept of Bloom's Taxonomies:

TABLE 3
COGNITIVE LEVELS OF THINKING [10] [1]

The cognitive processes dimension — categories, cognitive processes (and alternative names) Lower order thinking skills ⟶ Higher order thinking skills					
Remember	Understand	Apply	Analyze	Evaluate	Create
recognizing (identifying) recalling	interpreting clarifying, paraphrasing representing, translating illustrating classifying categorizing summarizing concluding, . interpolating, predicting comparing explaining	executing carrying out implementing using	differentiating discriminating, distinguishing, focusing, selecting organizing finding coherence, integrating, outlining, parsing, structuring attributing deconstructing	checking coordinating, detecting, monitoring, testing critiquing judging	presenting hypothesizing planning designing producing construct

In order to apply the Bloom's Taxonomy in questioning the study the college introduced the following model (LO/IO/HO) for the staff to apply the concepts while setting the question papers [10].

In the implementation of the use of Bloom's Taxonomies to award the marks to the questions the following technique was adopted.

TABLE 4
CLASSIFICATION EXAMPLES AND BALANCING OF THE EXAMINATION PAPERS [10].

S. No.	Question	Classification as per Blooms Taxonomy (Cognition Level)	Percentage distribution recommended	Marks
1.(a)	Define Ohm 's law	LO(LOCQ)	20-30%	The marks are apportioned based on the total marks allotted for a question
(b)	What is the Root Mean Square value of an alternating current?	LO(LOCQ)	20-30%	
(c)	Classify the soils based on the data given	IO((IOCQ)	40-50%	
(d)	Design a pneumatic circuit for the application described	HO(HOCQ)	30-40%	

***LO** – LOCQ – Lower order cognitive questions – covering questions for testing the remembering and understanding of the concepts by the students. **IO** – IOCQ – Intermediate order cognitive questions-Covering questions that test the **applying and analyzing** skills of students.*

***HO** – HOCQ-Higher order cognitive questions-To test the **evaluating and creating** abilities of the students with respect to their knowledge.*

A number of recent studies have been conducted which use the taxonomy to improve teaching and learning, for instance in educating academic staff in test construction (Evans, 1999), improving literature reviews (Granello, 2001), assessing multiple choice examinations (Knecht, 2001), assessing higher order skills (Sanders, 2001), examining the education of actuarial students (Hardy et al., 1990) and to develop a parallel system in economics education (Hansen, 2001) [11]. In addition, it has also been used for defining academic quality (Nodrvall & Braxton, 1996) [11].

However, to our knowledge, the taxonomy has not been used to develop a quantifiable tool that will enable teachers to analyse the cognitive processes embedded in the objectives and assessment of a subject and the alignment of objectives with assessment tasks. This is similar to our concern and partly answers our objective of designing a model that would quantify the worthiness of the question set.

We were interested in their Step 1 – Numerical Rating for Bloom Taxonomy [11]: The first step in this process was to allocate numerical ratings to each of the 6 levels of learning of the Cognitive domain as indicated in Fig. 5 below. Note that the levels have been assigned weights accordingly.

TABLE 5
ASSIGNED WEIGHTS TO ACTION VERBS IN GROUPS

Cognitive Level	Assigned Weight
Knowledge	1
Comprehension	2
Application	3
Analysis	4
Synthesis	5
Evaluation	6

Our model assigned weights to the verbs. For example the question that begins with " **Compare** and **contrast ….**" Would have a score of 4 + 4 = 8. The reason being that the question has two verbs from level 4 (Analysis) ; compare one

verb and contrast another verb giving a total of 8 marks or points. If, however, the aim asked for the student to be able to '**explain and justify** …' the level of learning to be demonstrated is higher and more sophisticated [11].
Anderson and Krathwohl considered creativity to be higher within the cognitive domain than evaluation [12]. This research also interprets the latest and Revised Bloom's Taxonomies and outlined by Churches that most scholars have welcomed the revised Blooms Taxonomies. Fig. 4 shows Church's conceptualisation of the Blooms Cognitive Domain [12].

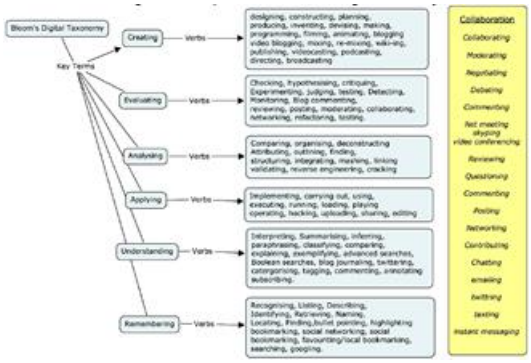


Fig. 4. Church's conceptualisation of the Blooms Cognitive Domain [12]

Mehmet Kaan Demir and Mustafa Yunus Eryaman [13] analyzed instructors' exam questions at a Primary Education Department in terms of the exam's period, the comprehensibility of the instructions, cognitive level, and the appropriateness to the critical thinking. They studied and analysed 100 randomly selected exam papers and 1,665 questions by three experts in the field [13]. The results concluded that the exam questions were generally at knowledge level in terms of cognitive domain and they were not appropriate to critical thinking [13].

TABLE 6
THE COGNITIVE LEVEL OF THE ANALYZED EXAM QUESTIONS

Cognitive Level	f	%
Knowledge	965	58.0
Comprehension	237	14.2
Application	248	14.9
Analysis	137	8.2
Synthesis	48	2.9
Evaluation	30	1.8
Total	1,665	100.0

The results in table 6 show that most of the questions were set to test knowledge. Knowledge is the lowest level in the Broom's taxonomies levels. Since this was done at primary school level it can be argued that this is normal since higher level taxonomies are rare to be tested at this level. This can be a serious source of worry if this is an analysis at University level where we expect students to demonstrate high level of critical thinking. The appropriateness level of the analyzed questions to critical thinking, are shown in the table below [13].

TABLE 7
THE APPROPRIATENESS LEVEL OF THE ANALYZED QUESTIONS TO CRITICAL THINKING [13].

Appropriateness to Critical Thinking	f	%
Inappropriate to Critical Thinking (Knowledge – Comprehension – Application)	1450	87,1
Appropriate to Critical Thinking (Analysis – Synthesis – Evaluation)	215	12,9
Total	1665	100,0

The analysis in table 7 also shows that 87% of the questions set were not appropriate to critical thinking. This could be typical of most examinations set by examinations boards.
Lecturers and teachers in universities and secondary schools tend to teach the way they were taught. Some lecturers would even repeat the questions that they themselves sat for way back. Some lecturers have very little knowledge on the implication of the questions that they ask their students. It's common for some teachers to give more questions that ask remembering and not skills. Once prospective teachers graduate from their programs without attaining high-level cognitive questions during their education, they do not prefer to assess their students' progress with high-level cognitive questions as a teacher [13].

III. METHODOLOGY

3.1 Challenges of Teachers and Lecturers Questioning Styles

Questionnaires were administered to 130 members of staff in both schools colleges of education and universities. The research reviewed that there are challenges that educators face in deciding the marks and using the right verbs to construct questions. This is as shown in the in fig. 5 below.

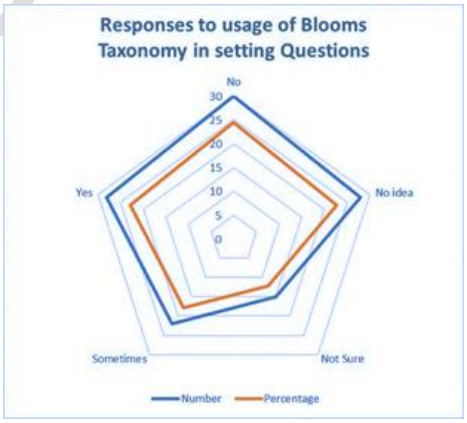


Fig. 5. Responses from respondents on whether they use Bloom's Taxonomies of the Cognitive Domain action verbs when setting examinations or test items.

As can be seen from the figure above there is a greater proportion of educators who do not really know whether they use the Blooms taxonomies is setting the questions. This number is close to 30% of the respondents who stated that they do not use the action verbs but we could see from their test papers that they actually use the action verbs except that they do not know the role such action verbs play in designing questions. The responses to No idea, Not sure and Sometimes also carried a great percentage of over 70%.

Respondents were asked to rate how much they use the Bloom's Taxonomies in setting questions for their students. Fig. 8 below shows the respondents responses to the question "Do you use Bloom's Taxonomies in setting questions?".

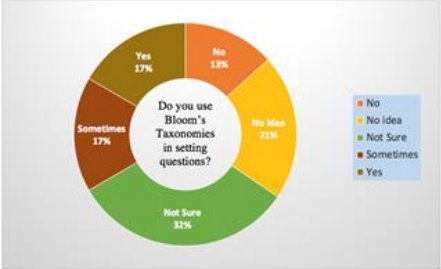


Fig. 6. Respondents' answers to the question that asked them how much they use the Bloom's Taxonomies in setting questions

Fig. 6 shows that there is a problem in schools, colleges of education and universities in designing questions using the Bloom's taxonomies. 32% of the respondents said that they were not sure as to whether they use the taxonomies or not. 21% had no idea. Comparatively these percentages are too high and cause a lot of concern. It is against this background that the recommender system was developed to assist the teachers and lecturers in designing standard questions.

3.2 Model Development

A prototype based on the model was designed and developed. The proposed model utilizes MySQL, PHP. The **PHP Hypertext Preprocessor (PHP)** is a programming language that allows web developers to create dynamic content that interacts with databases [18]. PHP is basically used for developing web based software applications [18]. PHP is a server side scripting language that is embedded in HTML [11, 1, 1].

IV. System Modelling

The following model was key to designing and developing the coding aspect of the system.

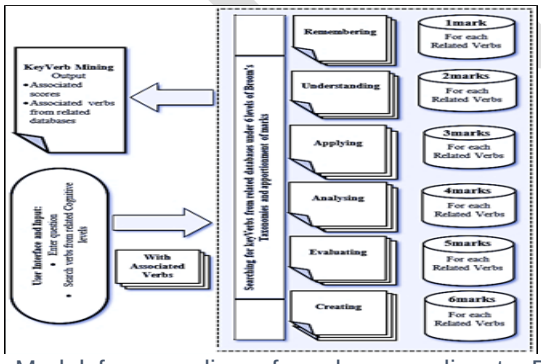


Fig. 7. Model for awarding of marks according to Blooms Cognitive Domain

Fig. 7 shows that the action verbs in a question are assigned marks according to the level where such verbs are found. This is the basis under which the programming in PHP was based as shown in the table below. Table 7 below shows how the system allocates marks to the questions.

TABLE 7
MANUAL AWARDING OF MARKS TO TEST ITEMS

Appropriateness to Critical Thinking	f	%
Inappropriate to Critical Thinking (Knowledge – Comprehension – Application)	1450	87,1
Appropriate to Critical Thinking (Analysis – Synthesis – Evaluation)	215	12,9
Total	1665	100,0

V. System Implementation

Open source software or full version trials were used to develop the system were open source. Open source tools are available at no cost to the user. In the development of the system the following tools were used [1]:

1. Apache Web server – for keeping data before its used
2. MYSQL – for manipulating databases
3. Hypertext Markup language – for creating webpages
4. Visual Studio Code – for coding and editing the codes
5. CSS – for styling web pages
6. Wamp Server for creating databases

The web application was developed with the use of Hypertext Processor (PHP). This application integrated the use of SHA3-224 cryptographic hash function to provide cyber security objectives and confidentiality, integrity and authenticity assurance on the part of the user [20]. The web application allows the user to interact with the system for examinations analysis to make them acceptable though the balancing of questions using the Blooms Taxonomies action verbs.

VI. Model For Strengthening Testing And Examinations Questions

The system architecture consists of basic steps: the pasting of the questions on the model that automatically converts it into plain text, analysing of the questions and giving feedback to the user. The user needs to register in order to use the system. The system stores the users' names in a secure location. Fig. 8 is the Graphical User Interface (GUI) for the system.

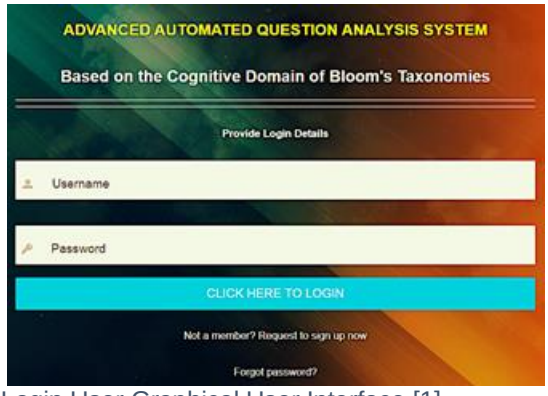


Fig.8. Login User Graphical User Interface [1]

Fig. 10 is user interface to the recommender system. This is where the user pastes the questions to be analysed.

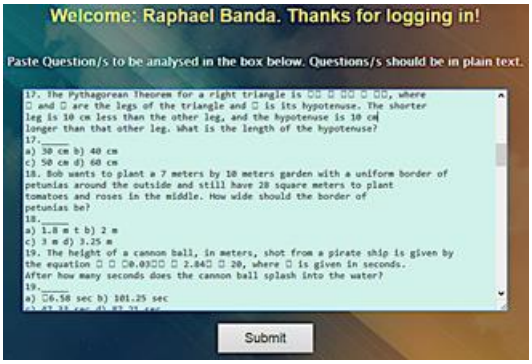


Fig. 9. Screen shot of Home GUI of Model [1]

We pasted the sample question as shown in the text box of the recommender as shown fig. 9. The system was able to analyse and count the frequency of action verbs used. Fig. 9 shows the input and Figs. 10 and 11 show the results of this input in analysis form and graph form respectively.

Question Analysis Results

Number of Action verbs found in test item under Remembering is 1
Number of Action verbs found in test item under Understanding is 1
Number of Action verbs found in test item under Applying is 7
Number of Action verbs found in test item under Analysing is 4
Number of Action verbs found in test item under Evaluating is 19
Number of Action verbs found in test item under Creating is 3

Total number of action verbs found in test paper is 35

Total marks under Remembering Level is 1
Total marks under Understanding Level is 2
Total marks under Applying Level is 21
Total marks under Analysing Level is 16
Total marks under Evaluating Level is 95
Total marks under Creating Level is 18

Remembering Percentage in the question/s is 0.65%
Understanding Percentage in the question/s is 1.31%
Applying Percentage in the question/s is 13.73%
Analysing Percentage in the question/s is 10.46%
Evaluating Percentage in the question/s is 62.09%
Creating Percentage in the question/s is 11.76%

Recommended total marks for the test item/s is 153

Fig. 10. Screen shot of Sample Output of test items [1]

The developed system can be used to analyse question papers to verify if the total number of marks given to the paper are appropriate [1].

The graph below shows the distribution of marks according to the findings above. Evaluating had a greater number of verbs used in the test paper. This implies that the paper is quite rich in upper level questions. This paper is suitable for upper secondary school. Also take note that the lower level action verbs were very few. If this paper was meant for the primary school learners, we expect the lower level cognitive domain verbs to take the lead.

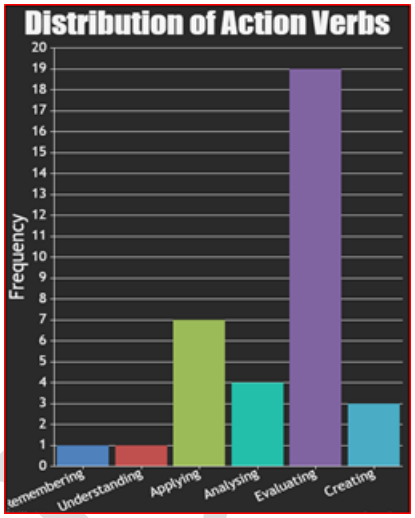


Fig. 11. Graph showing frequency of verbs in the analysed paper.

VII. Conclusion

Blooms Taxonomy is important when preparing examinations questions since they measure the correct skills based on the hierarchy and order of the action verbs used. System can be used for allocation of marks and standardizing assessment questions.

Computers cannot easily decode natural languages and such programs can be complex to program. It is this complexity that makes coding or programming the computer with natural language a great challenge. Complexity of natural language is the main challenge in text mining [1]. However when a programme is trained well this may not be an issue. In the awarding of marks to questions the system's ability to identify a particular verb from the horde of text and associate it with a weight was key to the project.

The proposed model can justifiably award marks to questions. With the implementation of text mining using MySQL Database platform, questions can be analysed according to the level of difficulty and justifiable marks awarded accordingly. The levels of difficulty will be drawn from the system's database of action verbs' domiciliate in the Cognitive Domain's level. The results obtained from the model can be used by the teachers and lecturers to prepare standard assessment questions.

The system can be further developed using neural networks or artificial intelligence.

VIII. Acknowledgment

The authors wish to thank Department of Computer Science for offering me the enabling environment to carry out my research. Another big thanks to the Directorate of Research and Graduate Studies for the useful comments and encouragement for us to carry out this research. We also extend my gratitude thanks to the Ministry of General Education for giving me permission to discuss with teachers and lecturers in schools and colleges of education respectively.

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