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Question Item Quality Analysis in Learning Content Management Systems (LCMS): A Case Study Based Approach

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Abstract

Nowadays Learning Content Management System (LCMS) has taken a major role in e-Learning evolution.Along many proprietory LCMS , Moodle, as an Open Source Software(OSS) based LCMS established itself as a major player in E-Learning deployment.Besides managing many activities under LCMS, assessment module is very important and crucial component. Most of the time we focus on performance issues of the Learners, implicitly ignoring the effectiveness of the assessment questions. Question Item analysis encompasses the process of collecting, summarizing the information from student’s responses to assess the quality of multiple-choice questions (MCQs). This article focuses on available features in LCMS along with a case study based approach towards assessing quality of MCQs in the light of few statistical parameters as Facility index (Fp) and Discriminative Efficiency (DEp), Discrimination efficiency (Dp) etc. So here we are to get interpretation of quality parameters to evaluate overall standard of multiple-choice questions (MCQs). As in near future standardization of web based learning management systems along with question item analysis will significantly influence assessment practices.

Key words

LCMS, E-learning, VLE, facility index, discriminative efficiency, discrimination index.

1. Introduction

Moodle platform is one of the most popular tools for Learning Content Management System, that allows relatively easily to create and manage e-learning courses along with taking online tests on the basis of MCQs. Moodle can be successfully used both in the educational system, and in private or public institutions. Moodle can be used in universities in various purposes, both in full-time and part-time learning, e-learning or blended learning, both in the initial and continuous formation. [1] Students progress checking is one of the most important and crucial components of this platform, i.e. Quiz, Assignments and Exercise. Questions that are created and stored in the Moodle database Question Bank and may be used randomly during the examination. Immediate evaluation of students' answers after test completion added a special feature. Therefore, a student may immediately or later on obtain information regarding the grade as well as detailed data concerning mistakes what he or she has made, in the form called "Feedback" report. Moreover, each test is scheduled for a time limit. In order to evaluate the quality of individual sets of questions, simplicity of individual variations, frequency of the used questions in the whole Question Bank were compared. Day by day new technologies provide teaching community with many interesting and effective tools that can be used to improve the teaching–learning process. The usefulness of these tools keeps a strong appeal for teachers and educator to have more information about the advantages and possibilities of using technology in the classroom or beyond classroom as well as about the results obtained from their application [2]. Though Internet is great and readily available source of all kind of information, there are some specific web-based applications considered to be used as a teaching resource. These LCMS applications allow teachers and educators to provide the learners with study content of different varieties, as well as to interact with them in real-time. They also allow teachers to follow the learning process evolution and to know the performance of each student in specific activities or tasks. E-learning platforms (also known as a virtual learning environment (VLE)) are especially useful when teaching Science & Engineering. They allow usage and implementation of objects of many types such as: videos, mp3s, text documents, scanned images, links to other web sites or animations which can be used to show dynamically many physical situations and concepts are often critical to apprehend by the students. [3]

A virtual learning environment is a software system designed for supporting and managing teaching and learning. A VLE typically provides tools such as those for assessment, communication, content uploading, submission of students' work, administration of student groups, questionnaires, tracking tools, wikis, blogs, chats, forums, etc. over internet. A VLE is a computer program that facilitates the so-called e-learning (electronic learning). Such e-learning systems are sometimes also called Learning Management System (LMS), Learning Content Management System (LCMS), Course Management System (CMS), Managed Learning environment (MLE), Learning Support System (LSS) or Learning Platform (LP); it is education system via Computer-Mediated communication (CMC) or online education. [4]

Some of them are commercial software, whereas others are open-source software (OSS). Among them are WebCT and blackboard http://www.blackboard.com (that merged in 2005). Open-source platforms are Moodle (http://moodle.org), Atutor (http://www.atutor.ca), Ilias (http://www.ilias.de) and Claroline (http://www.claroline.net/) All these applications have common features, but some of them are more flexible and complete in specific aspects, such as role assignments, chats management, assessment management etc.

Development of Moodle is undertaken by a globally diffused network of commercial and non-commercial users, led by the Moodle Company based in Perth, Western Australia.

Interactivity and automatic assessment are keywords to keep the learners' motivation and promote active learning [5][6][7]. And Moodle comprises of a bunch of interactive modules. Moodle with i-Assign, an interactive deployment by Rodrigues, Brandão. [8] on their observation all teachers that participated on the experiment agreed that using Moodle with i-Assign could help them to promote and improve learning.

Among many features we have focused on assessment module on Moodle. Quiz is the Moodle module associated with authoring and assessment [9]. By using Quiz, one can build questionnaires (quizzes) with automatic assessment resources. The quizzes may adopt several types of questions, including multiple choice, true-false, and short answer. Also, Quiz questions can be stored in a "question bank" to be further reused. [10]

Our study was based on MCQ responses from students of different categories as MCQs are very frequently used to assess students in different educational streams for objectivity and wide coverage in less time. MCQs are used mostly for comprehensive assessment at the end of academic sessions as well as provide feedback to the teachers on their educational activities. [11]

Question item analysis examines the student responses to individual test items (MCQ) for assessing the quality of those items and as well as of overall test. [12] The aim of the study was to analyze the quality of MCQ's by some statistical parameters. To investigate the relationship of items having good discriminative property as well as of standard facility index.

Though the fact that computer-based examination methods are well-established in academic centers, continuous monitoring of their quality is still needed and essential. [13] The Quiz module opens a possibility of analysis of individual MCQs considering their quality parameters, such as range of difficulty or differentiating ability reflected here by Facility Index and Discrimination

Index, [14] which is very important in the light of evaluation of an exam question repository and improvement of MCQs for the needs of further development.

2. Dataset Specification (Source)

The resulting data used for analyzing quality of questions were obtained from two different test cases:

Case 1: Online Tests performed on a group of 21 students of BSc (Bachelor Degree) who were the prospective candidates of MCA Entrance Test. The obtained results were generated from 40 no, four-option MCQs of Aptitude and 50 no, four-option MCQs of Mathematics.

Case 2: Online Diagnostic Tests performed on 366 students of B. Tech (Bachelor Degree in Engineering) 1st year students. The obtained results were generated from 10 no, four-option MCQs for each subject as Physics A, Physics B, Physics C, Mathematics, Chemistry and English.

3. Method

In order to carry out the on-line test, a Quiz tool of Moodle was used. The entire process is depicted as follows:

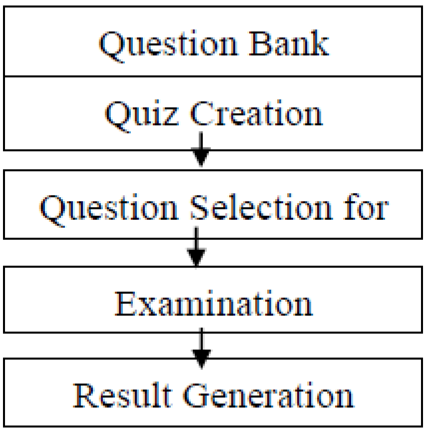


Fig.1. Flowchart for Entire Process of Online Test

4. Statistical Analysis of Question [15] [16]

4.1 Notations Used in the Calculations

We are considering here total number of eligible students for this online quiz is S.

Moreover, we have a lot of student s$\in S$, who have completed at least one attempt on the quiz.

The test has total number of positions P and we are considering number of positions $p \in P$.

The test is assembled from a number of questions $i \in I$.

(1) Because of random questions, different students may have received different questions in different positions, so i(p,s) is the item student S received in position P for question i.

Let Is be the set of questions that a student S can see. Let S_i be the set of students who attempted question i.

Each position has a maximum and minimum possible contribution to the test score, $x_p(\min)$ and $x_p(\max)$. In Moodle, $x_p(\min)$ is always zero. $x_p(\max)$ is the maximum grade of the question in the database.

Then, each student achieved an actual score x_p (S) on the item in position P.

So $x_p(\min) \leq x_p(s) \leq x_p(\max)$.

Intermediate calculations

To simplify the form of the formulas below, we need some intermediate calculated quantities as mentioned below:

Each student has a total score

$$T_s = \sum_{p \in P} x_p(s) \tag{1}$$

Similarly, there are the maximum and minimum possible test scores

$$T_{max} = \sum_{p \in P} x_p(l \max) \text{ And } T_{min} = \sum_{p \in P} x_p(\min) \tag{2}$$

Student's rest of test score for a position:

$$Xp(s) = T_s - x_p(s) \tag{3}$$

For any quantity that depends on position (for example x_p orX_p), its average is denoted with an over bar, and is an average over all students, so

$$\overline{x}_p = \frac{1}{s} \sum_{s \in S} x_p(s) \tag{4}$$

When a quantity is a property of a question, a bar denotes an average over all students who attempted that question, so

$$X_i = \frac{1}{S_i} \sum_{s \in S_i} x_i(s) \tag{5}$$

Similarly we have the variance of a quantity depending on position: $V(x_p) = \frac{1}{s-1} \sum_{s \in S} (x_p(s) - \overline{x}_p)^{\,2}$ and for a quantity depending on items:

$$V(x_i) = \frac{1}{S_i - 1} \sum_{s \in S_i} (x_i(s) - \overline{x}_i)^{\,2} \tag{6}$$

Finally, we need co-variances of two quantities, for example:

$$C(x_p, X_p) = \frac{1}{S-1} \sum_{s \in S} (x_p(s) - \overline{x}_p)\,(X_p(s) - \overline{X}_p) \tag{7}$$

where x_p denotes marks of the question at position p and X_p denotes marks of the question apart from position p.

$$C(x_i, X_i) = \frac{1}{S_i - 1} \sum_{s \in S_i} (x_i(s) - \overline{x}_i)\,(X_i(s) - \overline{X}_i) \tag{8}$$

where xi denotes marks of the question I and Xi denotes marks of the question i.

4.2 Position Statistics

Here we analyze the psychometric quality of the quizzes which can help us to test whether there are appropriate questions, well chosen to demonstrate concepts and of an appropriate level of difficulty and whether the questions discriminate between higher and lower abilities. Again Moodle offers a range of resources to carry out a psychometric analysis of a particular quiz, namely the Facility Index (FI), the Discrimination Index (DI) and the Discrimination Coefficient (DC). [17]

4.2.1 Facility Index

This is the average score on the question, expressed as a percentage:

$$F_p = 100 \frac{\overline{x}_p - x_p(\min)}{x_p(\max) - x_p(\min)}\,. \tag{9}$$

The higher the facility index, the easier the question is.

Tab.1. Interpretation of Facility Index [2]

Facility Index	Interpretation
5 or less	Extremely difficult or something wrong with the question.
6-10	Very difficult.
11-20	Difficult.
20-34	Moderately difficult.
35-64	About right for the average student.
66-80	Fairly easy.
81-89	Easy.
90-94	Very easy.
95-100	Extremely easy.

4.2.2 Standard Deviation

Again expressed on a percentage scale:

$$SD_p = 100 \frac{\sqrt{V(x_p)}}{x_p(\max) - x_p(\min)} \tag{10}$$

4.2.3 Discrimination Index

This is the correlation between the weighted scores on the question and those on the rest of the test. It indicates how effective the question is at sorting out able students from those who are less able. This is the product moment correlation coefficient between x_p and X_p, expressed on a percentage scale. That is,

$$D_p = 100r(x_p, X_p) = 100 \frac{C(x_p, X_p)}{\sqrt{V(x_p)V(X_p)}} \tag{11}$$

The idea is that for a good question (or at least a question that fits in with the other questions in the test), students who have scored highly on the other parts of the test should also have scored highly on this question, so the score for the question and the score for the test as a whole should be well correlated.

Tab.2. Interpretation of Discriminative Index [2]

Dp	Interpretation
50 and above	Very good discrimination
30 – 50	Adequate discrimination
20 – 29	Weak discrimination
0 – 19	Very weak discrimination
-ve	Question probably invalid

The weakness of this statistic is that, unless the facility index is 50%, it is impossible for the discrimination index to be 100%, or, to put it another way, if F_p is close to 0% or 100%, D_p will always be very small. That makes interpreting this statistic difficult.

4.2.4 Discriminative Efficiency

This gets around that weakness in the discrimination index by expressing C (x_p, X_p) as a percentage of the maximum value it could have taken given the scores the students got on this question, and the test as a whole. That is:

$$DE_p = 100\frac{C(x_p, X_p)}{C_{max}(x_p, X_p)} \tag{12}$$

Where $C_{max}(x_p, X_p)$ is defined as follows:

When you compute $C(x_p, X_p)$, you do the sum

$$C(x_p, X_p) = \frac{1}{S-1}\sum_{s\in S}(x_p(s) - \overline{x}_p)\,(X_p(s) - \overline{X}_p) \tag{13}$$

which involves a term for each student combining their question score and rest of test score. That is, you start with an array of $x_p(s)$ with an array of corresponding $X_p(s)$, one for each S. To compute $C_{max}(x_p, X_p)$, you just sort these two arrays before applying the above formula. That is, for the purpose of computing C_{max} , you pretend that the first student scored the lowest x_p and the lowest X_p, the second student scored the second lowest x_p and the second lowest X_p, and so on to the last student, who scored the highest x_p and X_p.

This statistic attempts to estimate how good the discrimination index is relative to the difficulty of the question.

An item which is very easy or very difficult cannot discriminate between students of different ability, because most of them get the same score on that question. Maximum discrimination requires a facility index in the range 30% - 70% (although such a value is no guarantee of a high discrimination index).

The discrimination efficiency will very rarely approach 100%, but values in excess of 50% should be achievable. Lower value of discriminative efficiency indicates that the question is not nearly as effective at discriminating between students of different ability as it might be and therefore is not a particularly good question.

4.2.5 Intended Question Weight

Intended weight is simply what we set up when editing quiz i.e, how much this question is supposed to contribute to determining the overall test score.

$$IQW_p = 100\,\frac{x_p(\max) - x_p(\min)}{T_{max} - T_{min}} \tag{14}$$

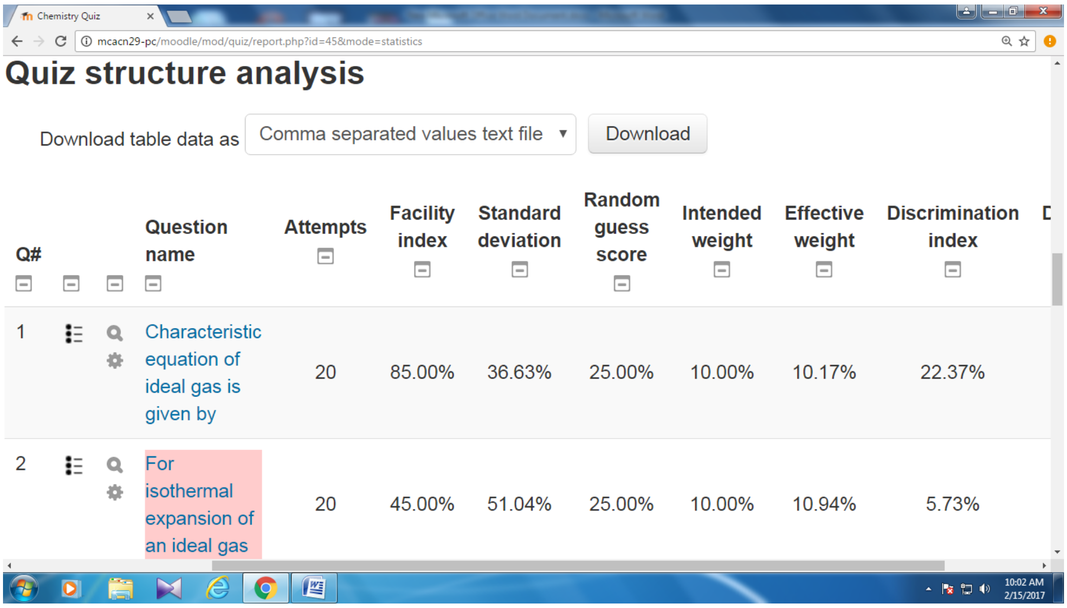
4.2.6 Effective Question Weight

The effective weight is an attempt to estimate, from the result, how much of the actual variation is due to this question. This is an estimate of what proportion of the variance in the students' test scores is due this question.

$$EQW_p = 100\,\frac{\sqrt{C(x_p,T)}}{\sum_{p\in P}\sqrt{C(x_p,T)}} \tag{15}$$

If the effective weight is greater than the intended weight it shows the question has a greater impact in the spread of scores than may have been intended. If it is less than the intended weight it shows that it is not having as much effect in spreading out the scores as was intended.

5. Result


Quiz structure analysis

Download table data as Comma separated values text file Download

Q#	Question name	Attempts	Facility index	Standard deviation	Random guess score	Intended weight	Effective weight	Discrimination index
1	Characteristic equation of ideal gas is given by	20	85.00%	36.63%	25.00%	10.00%	10.17%	22.37%
2	For isothermal expansion of an ideal gas	20	45.00%	51.04%	25.00%	10.00%	10.94%	5.73%

Fig.2. Quiz Information for Online Diagnostic Test (Chemistry)

Tab.3. Quiz Structure Analysis

Q#	Facility Index	Standard Deviation	Intended Weight	Effective Weight	Discrimination Index	Discriminative Efficiency
1	85.00%	36.63%	10.00%	10.17%	22.37%	33.33%
2	45.00%	51.04%	10.00%	10.94%	5.73%	7.56%
3	5.00%	22.36%	10.00%		-17.48%	-48.15%
4	20.00%	41.04%	10.00%	7.29%	-4.54%	-6.38%
5	65.00%	48.94%	10.00%	12.35%	20.00%	26.61%
6	15.00%	36.63%	10.00%	8.99%	12.25%	18.92%
7	10.00%	30.78%	10.00%	9.38%	26.42%	45.45%
8	50.00%	51.30%	10.00%	15.34%	46.82%	68.42%
9	55.00%	51.04%	10.00%	14.41%	36.41%	50.98%
10	85.00%	36.63%	10.00%	11.13%	31.97%	46.67%

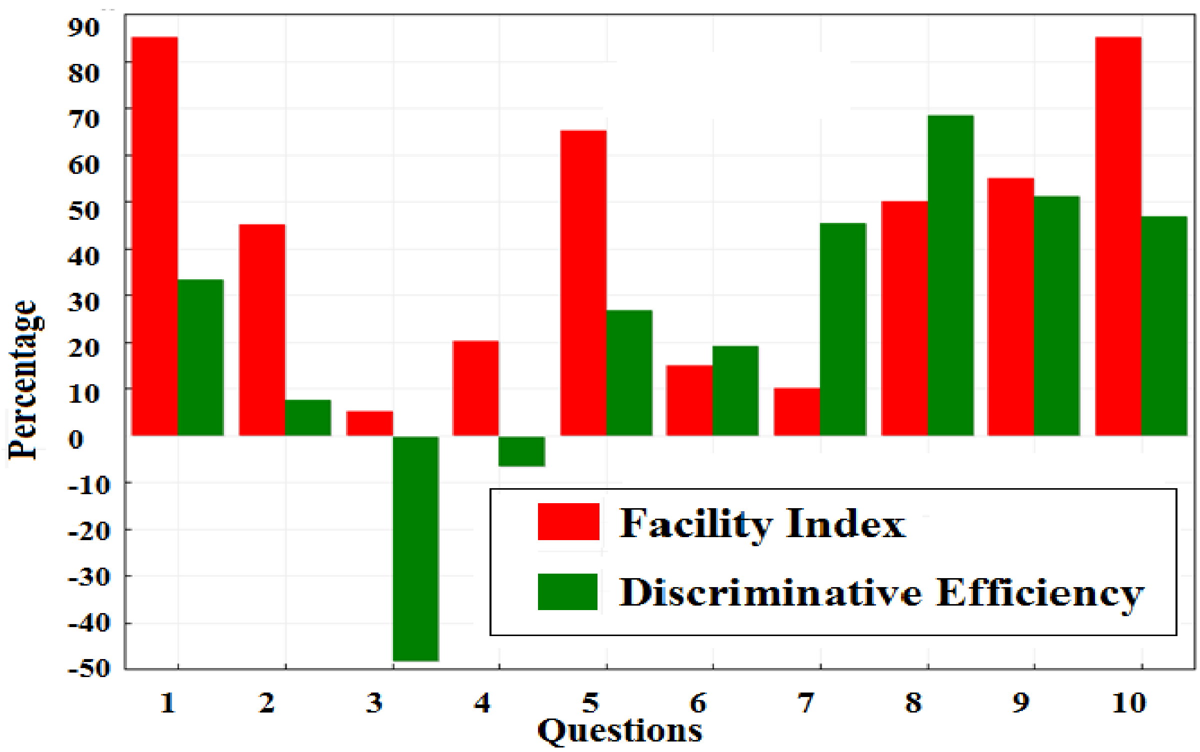


Fig.3. Bar Chart Representation between Facility Index and Discriminative Efficiency

6. Observations

By comparing the discrimination efficiency with the facility index we can get the measure of how effective the quiz is.

i) From Figure-3, we obtain a comparative analysis of Facility Index and Discriminative Efficiency of 10 questions.

ii) In the above figure, Q1 and Q10 have a higher facility index which implies that these questions are too easy considering the table-1.

iii) On the contrary, Q3 is Extremely Difficult, Q7 is Very Difficult and Q6 is Difficult as there Facility Indexes are 5%, 10% and 15% respectively.

iv) Q5, Q8 and Q9 are comparatively standard questions for the average graded students.

v) Lower value of Discriminative efficiency of Q2 & Q6 indicates that these questions are not nearly as effective at discriminating between students of different ability (grade discrimination).

vi)Negative value of Discriminative efficiency of Q3 & Q4 indicates that these two questions are probably invalid.

vii) Discriminative efficiency of Q8 indicates that this question is effective at discriminating between students of different ability.

viii) If facility index is 100% or 0%, there is no scope of discriminating the students. 100% means it is very easy question & 0% means it is very tough question, so effective weight is 0 and discriminative efficiency & discrimination index is NULL (no value).

ix) The effective weight is a proportion of the square root of the covariance of the question with overall performance. If the question's scores vary in the opposite way to the overall score, this would indicate that this is a very odd question. And for that the effective weight cannot be calculated. This happens for Q3 which has no value for effective weight.

Conclusion

Question Item analysis is a simple yet valuable procedure performed after the examination providing information regarding the quality and validity of an item/test by calculating Facility index, Discrimination index, Discrimination efficiency, and their interrelationship. An ideal item (MCQ) will be the one which has average Facility index between 50% and 70%, high discrimination ($Dp > 30\%$), and In this study, the majority of items fulfilled the criteria of acceptable difficulty level and good discrimination. Easy items with poor discrimination index will be reviewed and restructured. The results of this study should show a change in improving quality of MCQ test items for any examination, and leading to development of proper assessment strategy as part of the curriculum development. Much more of these kinds of analysis should be carried out after each examination to identify the areas of potential weakness in the one best answer type of MCQ tests to improve the standard of assessment [4]. Finally It should initiate and motivate the use and study of this assessment component of LCMS in broader perspective towards the standardization of question item selection strategy.

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