Volume: 6, Issue: 1
Page: 1- 16
2024

ISSN: 2707-8965 (Online) & 2708-3772 (Print)

Euro Afro Studies International Journal®
(EASIJ.COM)

Effectiveness of Multiple Choice Based Questions in Mathematics Assessments

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Abstract:

This study aims to prove the quality and effectiveness of Multiple-Choice Questions (MCQ) based assessments in Mathematics course offered in School of Foundation Studies (SoFS) at National University Science and Technology, Oman. The General Foundation Program (GFP) Oman at SoFS prepares the students prior to undergraduate studies. For Mathematics course, SoFS follows the outline suggested by Oman Academic Standards for GFP set by National Quality Plan (OAAAQA - General Foundation Programme Accreditation, n.d.). However, Oman Academic Standards does not specify any assessment strategies for the course, each Higher Education Institutions (HEI's)decides their own. Inconsistency in measuring all the Learning Outcomes (LO's) of Mathematical courses was observed during the descriptive assessments over the past 10 years triggered in replacing the assessments with MCQ. As a result, an integrated assessment with the combination of descriptive and MCQ was introduced, and a comparative study was conducted. Based on the outcomes, later the assessment was completely replaced with MCQ. Detailed analysis of the results of the cohorts in both Spring and Fall semesters of the academic year 2022-2023 & Fall semester of academic year 2023-2024 has been done for around 425 students in each semester. The study was conducted with the help of statistical approach and conclusions. Using the tools, Cronbach Alpha, Standard Deviation and Coefficient of Variation, the study proved reliability of MCQ assessment in measuring all the proposed LO's by Oman Academic

EASIJ
Accepted 25 January 2024
Published 31 January 2024
DOI: 10.5281/zenodo.13996070

Standards by emphasizing the chances of student critical thinking. This study emphasizes having MCQ in any form of Mathematics assessments and proves the consistency and reliability of MCQ based assessment over Descriptive.

Keywords: Reliability of Multiple-Choice Questions (MCQ), Mathematics Assessment, General Foundation Program (GFP)Oman, Cronbach Alpha, Standard Deviation, Coefficient of Variation,

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Introduction:

In Oman, a General Foundation Program (GFP) is a mandatory requirement prior to any undergraduate studies, which prepares students for their higher education. In 2006, one of the goal sets by Oman Authority for Academic Accreditation and Quality Assurance (OAAAQA) is to review the GFP to ensure the quality of the GFP offered across the country. As per Oman Academic Standard (OAS) set by OAAQA, a foundation program is composed of four areas namely English, Mathematics, Computing and General Study Skills. Each Higher Education Institution (HEI's)is responsible in setting the course delivery plan and assessment strategies as per the guidelines provided by OAS. GFP in Oman plays a vital role in preparing the students for effective engagement in higher education. (OAAAQA - General Foundation Program Accreditation, n.d.)

Oman's education system aims to balance modern educational practices with cultural heritage, preparing students for global citizenship while nurturing local values. The curriculum meets global benchmarks while incorporating local culture along with the integration of modern technology. Increased emphasis on science and technology to prepare students for modern jobs. Basic Education lasts for 10 years from grade 1 to 10, followed by two years of post-Basic Education system (secondary education). After the secondary education students study a one-year foundation course which prepares them for higher education or vocational training. (Nasser, 2019)

National University Science and Technology Oman provides a strong foundation program to the students with a combination of curricular and extracurricular activities. The GFP at National University, the School of Foundation Studies (SoFS) composed of three modules namely English, Mathematics and Computing Skills. GFP in SoFS is one-year program consisting of two semesters namely F1 and F2. To get admission at National University, the student must go through a placement test, based on the outcome of the test results, student will be enrolled in different levels of foundation (F1 or F2). In GPF, each module assessment consists of coursework and final examination, with a passing criterion of 50% aggregate in each module with condition of a minimum of 50% in coursework and final examination. (National University, 2024)

Since the establishment of the University, the SoFS has been following a descriptive based assessment in Mathematics module. During covid 19 pandemic time, the entire assessment pattern shifted to online MCQ and later a combination of MCQ and descriptive assessments in mathematics. A detailed comparison was made based on these two different contexts of assessment. Even though both MCQ and Descriptive assessments have their own merits and demerits, the study reached a conclusion that MCQ based assessments have more advantage over descriptive. Hence this study suggests implementing a complete MCQ based assessment in Mathematics Module.

Literature Review:

A detailed review on Assessment for learning in Mathematics using MCQ's by Dr Mari Chikvaidze was done and according to Dr Marie, MCQ helps to assess learners conceptual understanding very effectively. The advantages of using MCQ's in mathematics assessment are its versatility, reliability and validity. MCQ's are easier for students to complete, and teachers can assess more content, the validity of such assessments are more. Also, with the use of technology, marking can be done very efficiently. MCQ assessments are less time consuming and can be conducted to many students than other tests methods. Using MCQ assessments different types of learning outcomes like critical think skills and analytical questions. (Chikvaidze, 2016)

Pros and Cons for effective assessments by Shelley explains the different advantage of MCQ in assessment. Shelley found that they are easy to grade and score, which is very helpful in large classroom grading. As the answer is predetermined, it reduces the potential grading and MCQ's can be used to test a vast number of topics. MCQ are ideal for time sensitive assessment as it can be done very quickly. Shelly also pointed out that MCQ assessments can be more effective in the proper context when used correctly. (Shelley, 2023)

A Teaching Guide for Higher and Professional Education points out that MCQ's are used to acquire high evaluation efficiency. MCQ assessment can be done using e learning which helps to provide both teachers and test takers with feedback on the acquired competencies and thus helps teaching learning process more effective. Creating good MCQ tests will avoid guessing answers and thereby making tests more reliable. By creating and designing high standard MCQ tests, increase the validity and reliability of the test. The validity of the MCQ test can be strengthened if the content to be tested is in alignment with the learning objectives. The respective level of difficulty and the learning environment. The article emphasized that MCQ test could address demanding cognitive processes on the level of understanding, analysis and application. (Review of Multiple-Choice Questions- a Teaching Guide for Higher and Professional Education, n.d.)

Statement of the Problem:

Detailed analysis of the results of the cohorts of SoFS, National University Science & Technology, Oman in both Spring and Fall semesters of the academic year 2022-2023 & Fall semester of the academic year 2023- 2024 has been done. The data has been collected from the results of cohorts in Midterm and Final exam of Fall and Spring semesters of the academic year 2022-23 and Mid and Final exam of Spring 2023-24. As a result of the comparison between the performance of the same cohort in MCQ and Descriptive assessments during the academic year Fall 2022-2023, a difference in performance level was observed. This triggered the idea of continuing similar studies in the spring 2022, Fall 2023 and Spring 2023 to check which pattern is more effective in covering the proposed learning outcomes in a proper manner.

Objectives:

1. Evaluate the Cronbach Alpha for each type of assessment to check the reliability.
2. After checking the reliability, calculate the Standard Deviation to check the distribution of marks.
3. Finally calculate the Coefficient of Variation to check the constituency of mark distribution.
4. Analyze the statistical data to compare the effectiveness of assessment proposed.

Research Methodology:

Each semester, the results of around 425 students have been analyzed. The initial stage was calculating the Cronbach Alpha for each assessment.

Cronbach Alpha

Cronbach Alpha is an important tool in evaluating and comparing assessments. Cronbach Alpha is considered as a tool of test reliability. Cronbach Alpha helps us to evaluate the reliability of the assessments and enhances the accuracy in interpreting the results. It helps in analyzing the consistency in understanding of a particular subject. It helps the test writers to understand the quality of assessment and gives accurate evaluation of the test takers. (Statistics by Jim, n.d.)

$$\text{Cronbach Alpha is calculated by } \alpha = \frac{N * \bar{c}}{\bar{v} + (N-1) * \bar{c}}$$

Where N – number of items, $\bar{c}$ – mean covariance between the items and $\bar{v}$ – mean item variance. The value of α ranges from 0 to 1. The acceptable values of α are between 0.70 to 0.95

Cronbach Alpha measures the internal consistency in an assessment which describes the relations between the items within the test. This tool shows the reliability of the assessments which in turn measures the errors also. The higher the value of α, the reliability and consistency of the assessment is more. The higher the reliability, the lesser the errors among the test takers. When the Cronbach Alpha is high, it shows that the different parts in the assessments are related more to each other. The low value of Cronbach Alpha shows poor reliability which reflects a low connection between the different parts of the assessment, hence it should be revised or avoided. (Making Sense of Cronbach's Alpha, n.d.)

Standard Deviation (SD)

Next stage was calculating the Standard Deviation (SD), a tool in Statistics which reflects the amount of variation among the data collected. SD measures the deviation of each value from the mean.SD measures the dispersion of the data. It helps to assess the variability of a student's response to each question. SD is calculated by finding the variation of each data

from its mean.SD help us to understand the variation in the data from an expected value namely the mean. (The Knowledge Academy, n.d.)

$$\text{SD is calculated by} \quad SD = \sqrt{\frac{\sum(x - mean)^2}{n}}$$

Where n is the total number. A SD between 0 to 10 indicates a consistent data set whereas s the value above 20indicates relatively an inconsistent data set.

A high SD shows greater variability in other words the points are widely dispersed from the mean whereas a lower SD indicates less variability pointing that the values are closer to the mean of the data. That means the higher the SD, the larger the variability in the data. The high value of SD in assessment shows that there is a large variation among the different questions. SD of a question paper reveals the vast spread out of different topics in the question paper. The low value of SD shows that the data are close to the mean which means that there is less variability and that the values are more consistent. Whereas the high SD shows the wide spread of the data which impacts the reliability and validity of the data. (How to Interpret Standard Deviation Results, n.d.)

Coefficient of Variation (CV)

Final stage was evaluating the Coefficient of Variation (CV), a statistical measure to assess the relative variability to compare the variation of different datasets.CV calculates the dispersion of data from mean.CV is calculated as the ratio of SD to mean which help in comparing the variation from one data to another even if the means are very much different from one another.CV is useful in comparing two or more types of data with different units or with different averages.CV is also considered as a relative Standard Deviation. (Coefficient of Variation - Meaning, Formula, Examples, Uses, n.d.)

$$CV = \left(\frac{\text{Standard Deviation}}{\text{Mean}}\right) \times 100\%$$

CV helps in comparing the degree of dispersion between different data.CV gives clear picture of the variability of the observation in relation to the average of the observation. CV shows the size of SD with respect to average. Higher CV shows the greater deviation from average whereas the lower CV shows that the variation from average is smaller which is more acceptable.CV helps in compute the relative measure of variability. For any data distribution the CV is acceptable up to 20% and if it is above 20%, the distribution is inconsistent and highly unstable. Hence a result distribution with a smaller CV is more consistent as it reflects the consistency in students' performance when compared with larger CV. (Hayes, 2024)

This study tried to identify the efficacy of MCQ based assessments over Descriptive type questions. In order to execute the data analysis, the current research identified Cronbach Alpha of the results of each semester considered. The result shows that MCQ based

assessment reliability is more than the Descriptive type in all assessments of each semester considered. Again, the study used Standard Deviation to demonstrate variability of student responses in MCQ assessment in each considered semester. Thus, the research proved variability of received and analyzed student responses supports the assumption of the study. This research also proved the reliability of results of MCQ based Math assessment conducted in various semesters during the academic years of 2022-23 and 2023-24 by applying the concept of Coefficient of Variation.

Results & Discussions:

The analysis was done on basic mathematics cohort for two years starting from Fall 2022-23. The sample size for each semester was 425.

Course Code	FBM001
Course Title	Basic Mathematics
Samples Collected (per semester)	425

The question paper for midterm and final exam was a combination of MCQ and Descriptive. The focus of analysis was comparing various statistical results in MCQ and Descriptive type. The analytical process started with finding the value Cronbach Alpha and the results are summarized for each semester as per **Table 1.1.**

Semester	Cronbach Alpha	
	MCQ	Descriptive
FE Fall 2022-23	0.89	0.71
FE Spring 2022-23	0.85	0.70
MT Fall 2022-23	0.83	0.74
MT Spring 2022-23	0.86	0.70

Table 1.1: Cronbach Alpha-MCQ& Descriptive

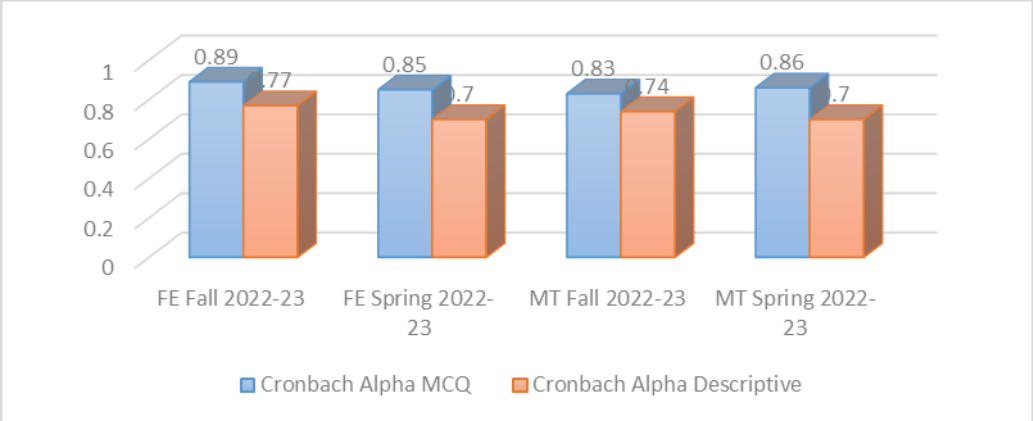

Chart 1.1: Cronbach Alpha-MCQ& Descriptive

As per **Table 1.1**, in all semesters the value of Cronbach Alpha for MCQ consistently is greater than 0.8, which indicates a high degree of reliability. However, the value of Cronbach Alpha for Descriptive is still in a good range, which shows a good degree of reliability. While analyzing both MCQ and Descriptive Questions, it was found that the Cronbach Alpha for MCQ is better than Descriptive Questions which indicates that the reliability is more in MCQ than in Descriptive.

After checking the reliability, the next stage was measuring the dispersion of the data. It helps to assess the variability of a student's response to each question. The Standard Deviation gives clarity on the distribution of each observation around a central value called mean or average of the given distribution. (Finding and Using Health Statistics, n.d.). A comparative analysis of Standard Deviation for MCQ and Descriptive part is shown in **Table 1.2.**

Semester	Standard Deviation	
	MCQ	Descriptive
FE Fall 2022-23	9.26	12.16
FE Spring 2022-23	7.9	11.67
MT Fall 2022-23	10.08	13.26
MT Spring 2022-23	8.26	10.98

Table 1.2: Standard Deviation-MCQ& Descriptive

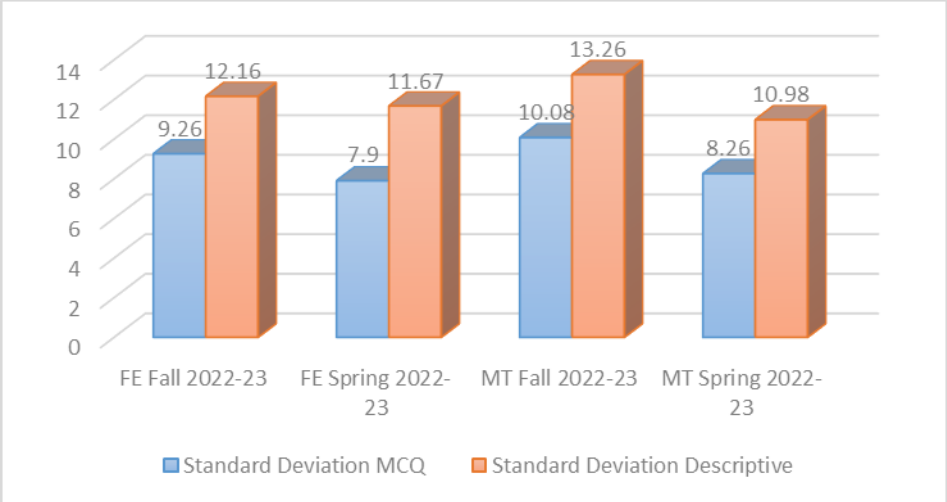

Chart 1.2: Standard Deviation-MCQ& Descriptive

The value of Standard Deviation for MCQ is constantly less than 10, which shows the variability of results in MCQ in a healthy range. So, each observation is relatively very close to the mean value, underlines the reliability of MCQ as stated before. At the same time, Standard

Deviation for Descriptive type is greater than 10 in each semester, but still in a good range. However, because of the comparison, MCQ part shows a consistency in the distribution of results.

The next stage of analysis was checking the consistency of the data set. The tool used was Coefficient of Variation. The Coefficient of Variation dictates the consistency among the data distribution provided.

Semester	Coefficient of Variation	
	MCQ	Descriptive
FE Fall 2022-23	12.61	14.17
FE Spring 2022-23	11.61	13.89
MT Fall 2022-23	12.1	16.56
MT Spring 2022-23	13.07	17.97

Table 1.3: Coefficient of Variation -MCQ& Descriptive

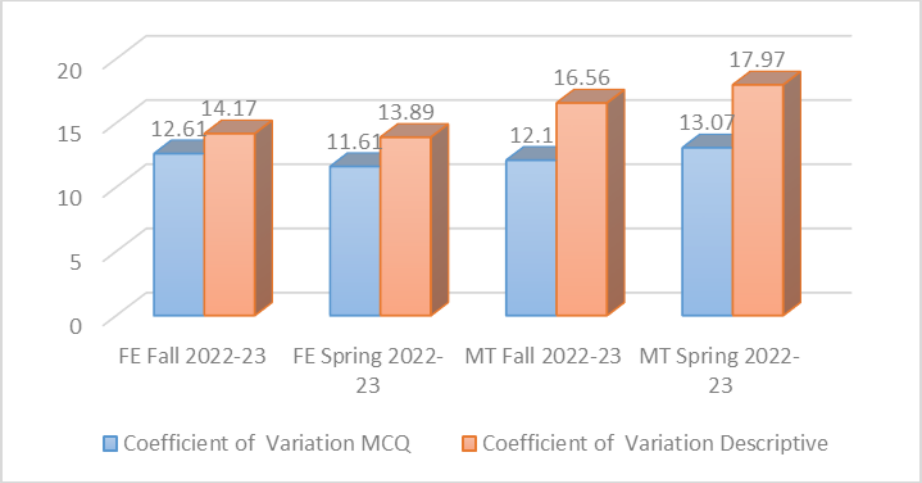

Chart 1.3: Coefficient of Variation -MCQ& Descriptive

From **Table 1.3**, it is clear that the value of Coefficient of Variation for MCQ part on average in each semester is less than 13, which shows a high degree of consistency in comparison with the Descriptive part with an average Coefficient of Variation above 15.

Based on the comparison and findings, the MCQ part shows a high level of reliably and consistency. Hence from the third year onwards the question paper was set only with MCQ's, and the results are shown in **Table 1.4.**

Semester	MCQ		
	Cronbach Alpha	Standard Deviation	Coefficient of Variation
Final Exam Fall 2023-24	0.82	9.06	10.62
Midterm Fall 2023-24	0.89	8.06	11.62

Table 1.4: MCQ Analysis-Fall 2023-24

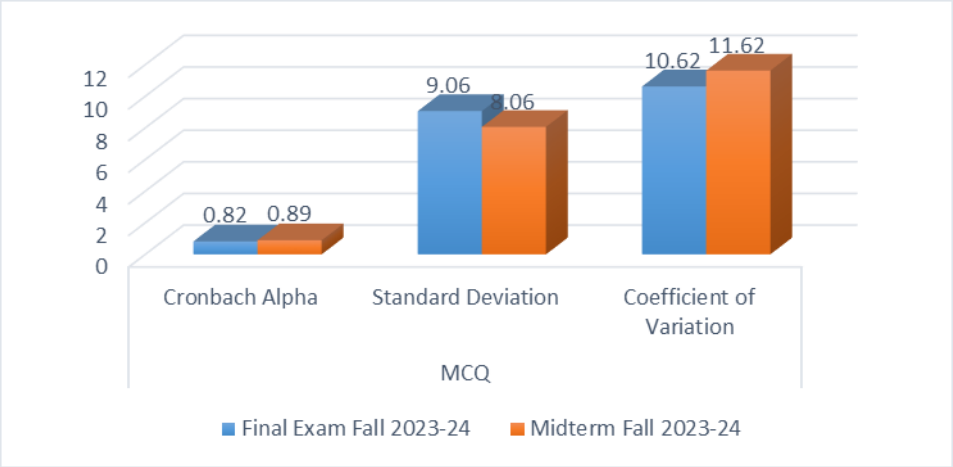

Chart 1.4: MCQ Analysis-Fall 2023-24

The results clearly indicate that the value of Cronbach Alpha, Standard Deviation and Coefficient of Variation is in an excellent range which supports the claim of the effectiveness of MCQ based assessments in Mathematics.

The findings are summarized in **Table 1.5** and **Chart 1.5** which summarizes the overall comparison.

Semester	MCQ			Descriptive		
	Cronbach Alpha	Standard Deviation	Coefficient of Variation	Cronbach Alpha	Standard Deviation	Coefficient of Variation
FE Fall 2022-23	0.89	9.26	12.61	0.77	12.16	14.17
FE Spring 2022-23	0.85	7.9	11.61	0.7	11.67	13.89
MT Fall 2022-23	0.83	10.08	12.1	0.74	13.26	16.56
MT Spring 2022-23	0.86	8.26	13.07	0.7	10.98	17.97

Table 1.5: Analysis Summary

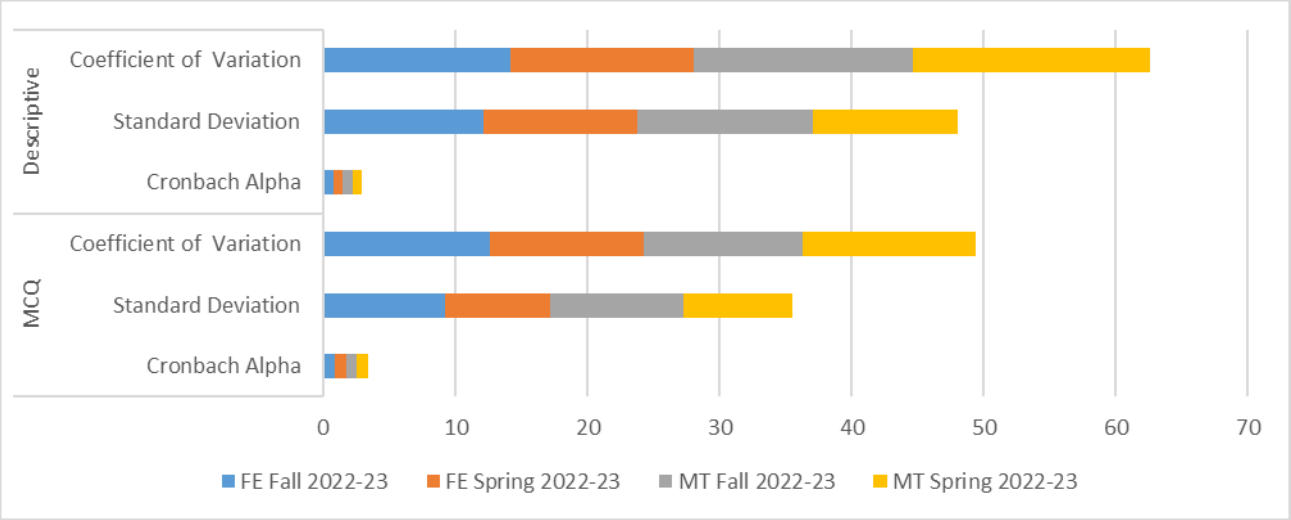

Chart 1.5: Analysis Summary

As a final stage, a comparative study has been done based on the response rate of the cohorts towards the higher order questions and the findings are summarized below.

Semester	MCQ	Descriptive
FE Fall 2022-23	26%	11%
FE Spring 2022-23	27%	14%
MT Fall 2022-23	23%	13%
MT Spring 2022-23	27%	18%
Final Exam Fall 2023-24	29%	
Midterm Fall 2023-24	28%	

Table 1.6: Higher Order Question Responses

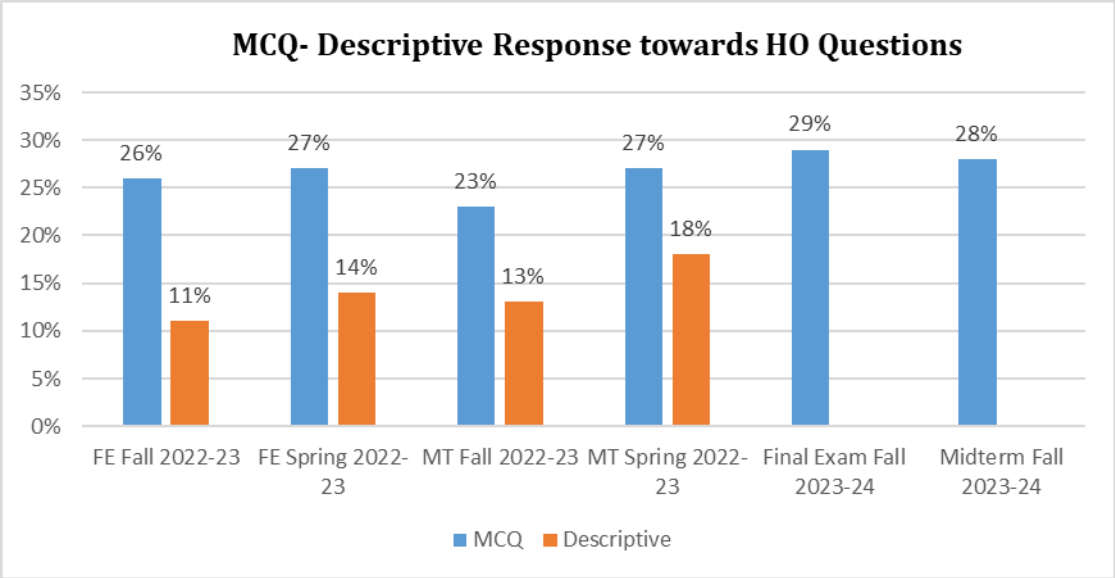

Chart 1.6: Higher Order Question Responses

Table 1.6 results clearly show a better response rate of the cohort towards the higher order question in MCQ's when compared with descriptive type, which proves MCQ's enhances the critical thinking of the cohorts in mathematics assessments.

Scope of the Study:

The General Foundation Program (GFP) Oman at SoFS prepares the students prior to undergraduate studies. For Mathematics course, SoFS follows the outline suggested by Oman Academic Standards for GFP set by National Quality Plan (OAAAQA - General Foundation Programme Accreditation, n.d.). As there is no national level assessment method for Mathematics course in GFP, this study suggests the assessment pattern followed at SoFS as a standard norm in all HEI's. Moreover, an MCQ based test can cover the entire proposed learning outcome in any course structure. It helps the evaluation procedure much easier, accurate and consistent. Whereas Descriptive evaluation is time consuming and inconsistent in marking. Analytical skills and critical thinking capacity will be tested more in MCQ's, which is a proven fact. MCQ pattern allows the exam setter to include a greater number of questions in a limited time frame. It helps the faculty to give feedback within a short period of time. MCQ based assessments can easily be conducted online, with zero logistics. An online based MCQ assessment is an added advantage in situations like pandemic. The result of the proposed study shows an enhancement in the critical thinking level of the cohort. Moreover, it proves the consistency and reliability of MCQ based assessment over Descriptive. So, this study emphasizes having MCQ in any form of Mathematics assessments as a national level norm.

Conclusions:

As per Oman Academic Standard for GFP, each HEI's developing their own assessment strategies for mathematics course in line with the proposed LO's. Difficulty in measuring all the LO's proposed was observed during the descriptive assessments leads initially to the integration of the assessments with MCQ and descriptive, later only with MCQ's. This research focuses on a comparative study between the results of both MCQ and descriptive based mathematics assessments by evaluating the Cronbach Alpha, standard deviation and Coefficient of Variation to prove the quality of MCQ based assessment over descriptive. This study proves the consistency and reliability of MCQ based assessment over Descriptive. MCQ pattern allows the exam setter to include a greater number of questions in a limited time frame. It helps the faculty to give feedback within a short period of time. The data analysis and results underline the claim of the study. Hence this study recommends MCQ based mathematical assessment as a national norm.

Even though Descriptive questions have their advantages, this study highlights the merits of MCQ as an effective method of assessment in Mathematics. With MCQ, evaluation is fairer as there is only one correct answer whereas in descriptive evaluation, it depends on marking of evaluators. MCQ provides a clear accurate marking of student's ability. In MCQ many LO's can be tested within an allotted time compared to descriptive. As in MCQ evaluation can be done as soon as test is over, immediate feedback can be given to students and analysis of data is easy compared to descriptive.

However, creating an MCQ question paper is really time consuming and challenging. It needs a lot of concentration to include distractors in MCQ to avoid easy selection of answers. While preparing an MCQ question papers, test writers should try not to give clues for the answers. Students can guess the answers for questions which they don't have any ideas of solution.

While preparing an MCQ question paper, test writers should take care to avoid overemphasizing on memorization. Options should be evenly distributed, and the statements should be made very clear. Test writers should include questions with critical thinking, application of concepts and with high order knowledge.

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Cite this article:

Author(s), Ms. Soji Binu Mathew, Mr. Sreehari Vellora Madathil, (2024). " Effectiveness of Multiple Choice Based Questions in Mathematics Assessments ", **Name of the Journal**: Euro Afro Studies International Journal, (EASIJ.COM), P, 1 –16. DOI: www.doi.org/10.5281/zenodo.13996070 , Issue: 1, Vol.: 6, Article: 1, Month: January, Year: 2024. Retrieved from https://www.easij.com/all-issues/

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