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Item Analysis Technique for improving Course Outcome Attainment

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Abstract: It has become a challenging task to derive information on attainment of cognitive skills by analysing students' performance. There are certain subjective critical factors such as understanding of basic concepts, quality of teaching, quality of question papers, and the mode of evaluation, which influence of students accomplishment. The authors feel that it is necessary to examine the attributes of end semester examination question papers. It is essential to assess the type of questions posed in the examinations using the statistical techniques and measures. This paper analyse the analysis of quality of questions used in the end semester examinations. The proposed methodology uses 'item analysis' technique for improving the course outcome attainment. Statistical results indicate that the question setters may consider the resulted norms while examining the students by standardizing the assessment questions, which in turn yield better academic performance by students.

Keywords: Item Analysis, Course Outcome Attainment, Student Performance, Question Paper Quality

1. Introduction

One of the fundamental aspects of teaching learning process is the assessment and evaluation of students' performance through examinations. As it decides the passing criteria (≥ 50%) for each student, the question setters have to take additional efforts to maintain with quality, in addition to the student learning outcomes assurance. Here, the term *'quality'* refers that the question paper is neither too hard nor too easy. The quality of each question has to be maintained and there should not be any compromise while setting the questions. This situation motivates to examine the nature and level of questions in the end semester examinations of different courses offered in an Engineering programme. The present study illustrates the complexity level of each question in respect of student response.

Agarwal et. al (2008) used Classroom Assessment Techniques (CAT) and Statistical Process Control (SPC) for analyzing the learning performance of students. The relationship between the students' readiness and their knowledge gain was projected in their performance analysis model. Arthur (2010) and Ajithkumar (2011) analysed the presence of Higher Order Thinking Skills (HOTS) questions and their quality parameters in the final examination questions of higher education. Sowmya et. al. (2015) explored the quality of question papers in alignment with the Bloom's taxonomy in knowledge domain and studied the level of HOTS questions. Huang et. al. (2013) developed predictor models by using Multiple Linear Regression (MLR) and Support Vector Machine (SVM) for predicting the academic performance of engineering students. They concluded that MLR was suitable to determine the average score for the class and SVM was suitable for individual score prediction. Gugiu (2013) used item analysis technique and recommended guidelines for improving the evaluation of student performance for political science courses.

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Serpil et. al. (2016) and Gul-Ar et. al. (2015) used item analysis technique for analysing the students' performance in multiple choice and essay type questions respectively. Jain et. al. (2018) drafted *question setting guidelines* to teachers so that that all types of learners would secure pass grade in the examinations. Himmah et. al. (2019) proposed that mathematics question papers should focus on HOTS level questions than LOTS in order to improve the problem solving skills of students.

Abubakar et. al (2017) analysed the various causes and effects for reduction in the student registration for advanced mathematics courses like Engineering Mathematics, Numerical Methods, and Statistics. The team recommended the local universities to involve in bridging the gap between the higher secondary and university education. Dragan et. al. (2017) analysed self reports and academic performance of students for detecting the learning styles of students. Direnga et. al. (2018) proposed an alternate method for analyzing pre and post test methods. The Discriminative Learning Gain (DLG) model described the learning level of students along with the discriminative effect of instruction compared with initial performance. Das Mandal (2018) categorized the questions based on their difficulty and complexity levels in his course on *Outcome Based Pedagogical Principles for Effective Teaching*.

Barak et. al. (2019) developed self-report tool for the self assessment of innovative thinking skills of individuals and evaluated their progress in different stages of study. Bothaina et. al. (2019) provided a comprehensive approach for predicting the academic performance of students by using regression models. They improved the accuracy by using ridge regression along with suitable feature selection and dimensionality reduction methods. Abirami et. al. (2020) used qualitative techniques like item analysis and co-efficient of variation to determine the quality of Engineering Mathematics question papers in relation with student performance in that course. Violante et. al (2020) proposed novel methodology using learning European Qualifications Framework (EQF), Bloom's taxonomy-based assessment questions and the QR code to help managing large class size for the formative assessment of the course engineering drawing, which in turn resulted in increased pass percentage and time reduction in uploading data in electronic register.

From the literature, the following inferences were made to make the assessment and evaluation of courses most effective:

- The course must have effective assessment and evaluation methods
- The evaluation should have follow-up activities like data analysis on the result
- The cognitive level of attainment of students have to be assessed
- The quality of questions have to be assessed so as to measure effectiveness and fairness of examinations

The paper is organized as follows: section 2 explains the motivation behind this work, section 3 describes the proposed methodology, section 4 discusses the results and section 5 concludes the paper.

2. Motivation

Bloom's taxonomy includes six different assessment levels like Remember, Understand, Apply, Analyze, Evaluate and Create. Instructors use these levels for assessing the performance of students in the knowledge domain. NEP 2020 expects the curriculum should facilitate the employability skills of students. Instructors have to set the questions such that logical thinking and creativity of students get enhanced. From the literature, it is understood that most of the research focused on examining the end semester examinations questions with respect of bloom's taxonomy in cognitive domain or done item level analysis for evaluating the quality of question papers. To our knowledge, limited research was done for assessing the quality of question papers using statistical techniques along with the students' performance. The motivation for this study is supported by the following research questions:

- RQ1: Can the quality of question papers be determined? Is there any relationship between quality of question paper and the results of exam? If so, how strong the relationship is?
- RQ2: Does the quality of questions contribute to Course Outcome (CO) Attainment?

This paper focuses on evaluating the quality of question papers of three different courses of Under Graduate (UG) Engineering programme. It assumes that if a student scores atleast ≥ 50% for all questions, then he/she would be getting 'pass' in the examination definitely. Finally, it recommends the framework and the set of guidelines that can be followed by the instructor while setting the question paper with quality.

3. Methodology

The paper focuses on assessing the quality of end semester question papers by using the statistical techniques. It tries to verify whether the questions support the attainment of higher level of cognitive skills. The overall framework of the proposed methodology is shown in Figure 1. The study has been carried out by setting the following research objective: to determine how far Item Analysis technique support Course Outcome Assessment for Engineering courses.

Difficulty Index or Facility value (FV) is the index for measuring the easiness or difficulty of a question paper. It is the percentage of students who have correctly answered and it varies from 0 to 1. Greater this value, easier the question items are; and vice versa. Discrimination Index (DI) is the indicator showing how significantly the question paper discriminates between "high" and "low" performing students. It varies from -1 to +1. Higher this value, the more would distinguish between high and low performers.

The different steps include:

(1) Collect Question wise Marks of Courses from the student examination database

(2) Run Item Analysis on the marks

(a) Arrange the data in descending order of the total score

(b) Identify High performing group (H_G) and Low performing group (L_G). H_G constitutes top 27% of students and L_G constitutes bottom 27% of students [Kelly, 1939].

(c) Determine the Quality attributes of the question paper - the Facility Value (FV), and the Discrimination Index (DI) using the Equations 1 and 2 respectively.

$$\text{Facility Value (FV)} = \frac{H_M+L_M}{M.2n} \quad \text{(Equation 1)}$$

$$\text{Discrimination Index (DI)} = \frac{H_M-L_M}{M.n} \quad \text{(Equation 2)}$$

where H_M is the sum of marks scored by H_G, L_M is the sum of marks scored by L_G, M is the maximum marks allotted for the item, and n is the number of students in the group.

(3) Calculate percentage of students who scored ≥ 50% for each question, the Response Value (Y)

(4) Tabulate the questions based on their attribute values FV and DI *(calculated by step 2)* and Y *(calculated by step 3)*. Group all questions based on their COs and compare CO attainment with their level of difficulty.

(5) Set the norms for attribute and their values for standardizing the question paper for improving CO attainment.

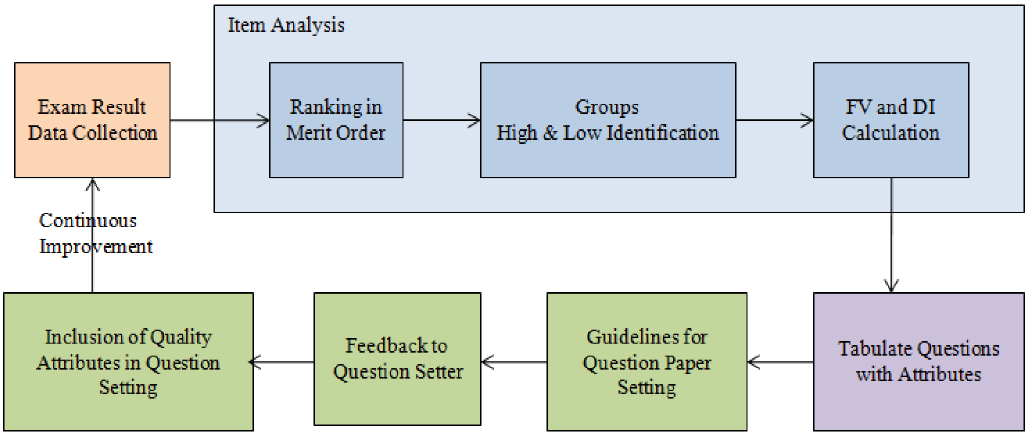

Fig. 1 Framework for Item Analysis Technique for CO Attainment Improvement

(6) The analysis report is shared with the question setters and recommended the guidelines for setting the questions.

4. Results and Discussions

Dataset Description

The end semester examination marks of the course Course_1 (*Data Structures)*, Course_2 (*Software Engineering)* and Course_3 *(Object Oriented Programming)* had collected for the same batch of students. It includes question wise marks of all 130 students who appeared for the exam. The Course_1 has 88% as pass percentage, Course_2 has 91% and Course_3 has 93%, where score ≥ 50% is considered as *'pass'* in the examination.

Table 1 Dataset Description

Course ID	Sections	Number of Questions	Marks allotted	Bloom's Category
Course_1	Part A	10	20 (2 marks each)	Remember
	Part B	5	40 (8 marks each)	Understand
	Part C	4	40 (10 marks each and either or type)	Apply
	Total	19	100 Marks	
Course_2	Part A	5	20 (4 marks each)	Remember
	Part B	5	30 (6 marks each)	Understand
	Part C	3	50 (10 + 20 + 20 marks and either or type)	Apply
	Total	13	100 Marks	
Course_3	Part A	10	20 (2 marks each)	Remember
	Part B	2	20 (10 marks each)	Understand
	Part C	4	60 (15 marks each and either or type)	Apply
	Total	16	100 Marks	

Each item in the question paper is set in alignment with the revised Bloom's taxonomy. Generally, Part A questions are at 'Remember' level, Part B questions are at 'Understand' level, and Part C questions are at 'Apply' or 'Analyze' level *(higher levels of Bloom's taxonomy)*. The structure of question paper of three courses Course_1, Course_2 and Course_3 are shown in Table 1.

In this paper, Part C questions are numbered like C1, C3, C5 and C7; and the questions C2, C4, C6 and C8 are their corresponding choice questions. To simplify the task, score given for the question C2 is taken for the question C1 and so on. Both questions C1 and C2 are related to the same course topic and with the same complexity level. Hence, there is no harm in considering this for Part C questions.

Item Analysis

Item analysis is done on the result data collected for the Course_1, by using the Equations 1 and 2.. Table 2 shows the quality attributes and their values for each question, when 27% of students are considered for H_G and L_G groups for the course Course_1. For example, the different attribute values of question A1 are: 0.73 FV and 0.29 DI for the course Course_1; and 93.85% students scored ≥ 50% marks for the question A1.

Table 2 Item Analysis Details of Course Course_1

Q No	Course_1_FV	Course_1_DI	Course_1_Y

A1	0.73	0.29	93.85
A2	0.43	0.39	47.69
A3	0.69	0.63	79.23
A4	0.42	0.33	60
A5	0.79	0.25	93.08
A6	0.74	0.4	90.77
A7	0.49	0.57	54.62
A8	0.23	0.29	33.08
A9	0.47	0.4	74.62
A10	0.54	0.39	73.08
B1	0.58	0.82	70
B2	0.41	0.47	61.54
B3	0.68	0.41	81.54
B4	0.65	0.56	73.85
B5	0.76	0.24	98.46
C1	0.81	0.31	92.31
C3	0.79	0.4	84.62
C5	0.67	0.37	82.31
C7	0.45	0.63	46.15

These FV and DI values exhibit the difficulty and discrimination indices of each item. Apart from these two measures, each item is analyzed along with its 'pass' percentage value (Y) for the categorization of 'Easy', 'Medium' and 'Hard' type of question.

Correlation Analysis

Initially, the relationship between the Response Value (Y) and the Facility Value (FV) / Discrimination Index (DI) values are analyzed through scatter plot, as shown in Figures 2 and 3. There exists positive correlation between the variables FV and Y. It is obvious that easier the item gives greater response values from the students, as shown in Figure 2.

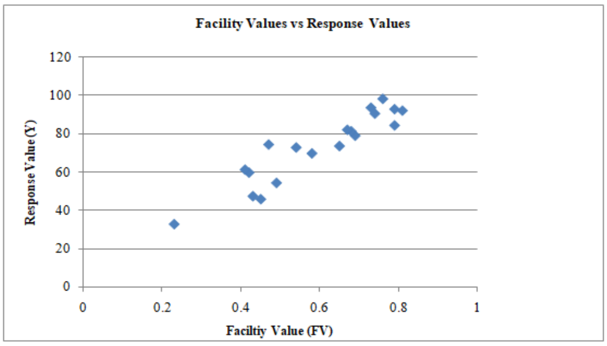

Figure. 2 Correlation between Facility and Response Values

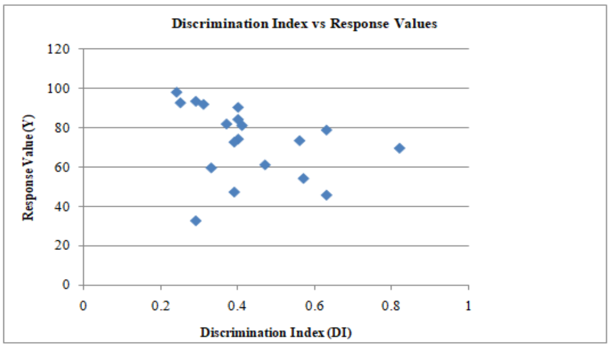

Figure. 3 Correlation between Discrimination Index and Response Values

There exists negative correlation between the Discrimination Index (DI) and the Response Value (Y). It is understood that the students' response is low, when discrimination index value is low, as shown in Figure 3.

Course Outcome Attainment

The Course_1 has six different COs and all of them are written at Apply level. Actual CO attainment has been calculated as follows: Questions are grouped for each CO as shown in Table 3. Percentage of score for each CO by each student is calculated. Percentage of students whose score is greater than CO target is determined.

Table 3 Course Outcomes and Questions Grouping

COs	Question Number	Actual CO Attainment
CO1	A1, A2, A3, B1, B2, C1	51.54%
CO2	A4, A5, A6, B3, C3	70.77%
CO3	A7, A8, C5	36.15
CO4	A9, B4	53.08%
CO5	A10, B5	56.92%
CO6	C7	24.62%

For example, total marks allotted for CO1 is 32 marks; 51.54% students obtained ≥ expected score for this CO1; 70.77% students for CO2. The expected score differs for each programme and for each course. It may be set based on the historical results of this course.

Categorization of Questions

The values of quality attributes are interpreted as follows: the item is classified as 'Easy' if $FV > 0.6$, 'Medium' if $0.4 \leq FV \leq 0.6$, and 'Hard' if $FV < 0.4$. The item is discriminated as 'Excellent' if $DI > 0.4$, 'Good' if $0.3 \leq DI \leq 0.4$, 'Fair' if $0.2 \leq DI < 0.3$, and 'Poor' if $DI < 0.2$. Greater the FV value, easier the item is; lesser the DI value, less discrimination between the H_G and L_G groups. These values are presented in the Table 4 where FV values are presented in horizontal direction, and DI values are presented in vertical direction.

The 19 questions of the Course_1 are categorized into different Quadrants based on its attribute values, as shown in Table 4. Quadrant 1 constitutes FI in Medium category and DI in Fair, Good categories. Quadrant 2 constitutes FI in Easy category and DI in Fair, Good categories. Quadrant 3 constitutes FI in Easy category and DI in Excellent category. Quadrant 4 constitutes FI in Medium category and DI in Excellent category, as shown in Table 4. For example, the question C1 is in Quadrant 1 with 92% students scored ≥50% marks for that question.

CO1 has 6 different questions namely A1, A2, A3, B1, B2 and C1 and this CO1 has contributed the highest for the course. However, the attainment was 51.54% only, as given in Table 3. All these 6 questions are distributed in all 4 quadrants. Though the item B1 has 70% pass percentage, it has very high DI; there has been minimum contribution from the L_G group and this item is not contributing for CO attainment. The item A2 has low DI value and it says that H_G group has also not performed well. The instructor may need to revisit the question and take additional measures from the aspect of content delivery.

Among the 6 COs, the CO2 has the highest attainment level, 70.77%, as given in the Table 3. The set of questions A4, A5, A6, B3 and C3 belonging to this CO2 fall in the Quadrants 1, 2 and 3, as shown in Table 4.

The CO6 has the lowest attainment value 24.62%, as given in the Table 3. Only one question has been set for this CO6. As its DI value is very high, the contribution from the L_G group would have been very minimum. This question is not part of any of the quadrants, hence it is very much difficult to get the expected attainment from this question.

Table 4 Categorization of Questions of Course_1

Excellent	**1**										
	0.9							B1 (70)			
	0.8										
	0.7					C7 (46)		A3 (79)			
	0.6					A7 (55)		B4 (74)			
	0.5					B2 (62)		B3 (82)			
Good	**0.4**					A2 (48) A4 (60) A9 (75)	A10 (73)	C5 (82)	A6 (91) C3 (85)	C1 (92)	
Fair	**0.3**			A8 (33)					B5 (98) A1 (94) A5 (93)		
Poor	**0.2**										
	0.1										
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
		Hard			**Medium**			**Easy**			

In order to have better CO attainment value from the question items, the quadrants 1 and 2 are preferred. However, few questions may take their positions in the quadrants 3 and 4 but at lower DI value. When questions occupy positions nearer to the left margin or top margin, then there may be risks that these question items may not contribute to CO attainment.

Table 5 shows the categorization of questions for the Course_1 w.r.t Bloom's level of Taxonomy. Nearly, 58% of questions are in Quadrants Q1 and Q2; 16% in Q3. Nearly 26% of questions are in Q4 and not part of any of the quadrants, which in turn ultimately lowered the CO attainment values. The questions in .Q4 are the most difficult and very few students would have given the attempt. The question setter may do the necessary analysis and revisit the question text used or focus on those COs and give more practice to the students.

Table 5 Categorization of Questions vs Bloom's Level

Course	Bloom's Level	Q1	Q2	Q3	Q4	Not in Quadrants	Total
Course _1	Remember	4	3	1	1	1	10
	Understand	0	1	2	1	1	5
	Apply	0	3	0	0	1	4
	Count	4	7	3	2	3	19
	Percent of Questions	**21**	**37**	**16**	**10**	**16**	

Similar process has been followed for courses Course_2 and Course_3 and the results are shown in Appendix 1.

5. Conclusions

The attainment of course outcomes becomes challenging now-a-days for Engineering programme courses. There could be various reasons for the poor results. As part of quality assurance activity, it becomes necessary to assess the quality of question paper with the statistical measures of item analysis technique along with the students' performance data. It would help the question setters to give the idea for having improved students' performance in the course. This type of research enables the Institute to set up Question Paper Standards for the entire curriculum.

This qualitative research has been conducted on the end semester question papers of three different courses. The quality attributes of each question have been determined using the item analysis technique and then analyzed with the pass percentage of students. It is seen that higher values of FI and lower values of DI would support for the better performance of students. Thus, the research question *(RQ1)* has been well addressed by this argument.

The question paper should be set *moderately* so that the items are not too difficult and not too easy. Also, the question has to be designed such a way that it makes the students to perform better for higher levels of Bloom's taxonomy questions. Using the values of quality attributes and the estimated student performance, the matrix has been built to categorize each question. It is required that the most of the questions should be in 'lower' quadrants, and few questions may be in 'higher' quadrants. Thus, the research question *(RQ2)* has been well addressed by this matrix.

Future work includes analysis on the quality of question papers of continuous assessment tests along with their results, aligned with the results of end semester examinations. Student feedback on the difficulty level of the questions immediately after their examinations may also be considered for assessing the quality of question papers.

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Appendix 1

Table A1 Item Analysis Details of Course Course_2

Q No	Course_2_FV	Course_2_DI	Course_2_Y
A1	0.39	0.29	51.54
A2	0.39	0.51	47.69
A3	0.86	0.26	90.77
A4	0.5	0.36	63.08
A5	0.79	0.18	93.08
B1	0.74	0.31	94.62
B2	0.62	0.53	73.85
B3	0.71	0.45	84.62
B4	0.64	0.55	70
B5	0.64	0.54	76.92
C1	0.81	0.27	93.08
C3	0.79	0.27	91.54
C5	0.57	0.42	67.69

Table A2 Course Outcomes and Questions Grouping for Course_2

COs	Question Number	Actual CO Attainment
CO1	A1, B1, B2	63.18
CO2	A2, C1	89.2
CO3	A3, C3	91.91
CO4	A4, B3, C5	86.24
CO5	B4	58.1
CO6	A5, B5	66.07

Table A3 Categorization of Questions of Course_2

Excellent	**1**										
	0.9										
	0.8										
	0.7										
	0.6							B2 (74) B4 (70) B5 (77)			
	0.5				A2 (48)		C5 (68)		B3 (85)		
Good	**0.4**					A4 (63)			B1 (95)		

Fair	**0.3**				A1 (52)				C3 (91)	A3 (91) C1 (93)	
Poor	**0.2**								A5 (93)		
	0.1										
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
		Hard			**Medium**			**Easy**			

Table A4 Categorization of Questions vs Bloom's Level – Course_2

Course	Bloom's Level	Q1	Q2	Q3	Q4	Not in Quadrants	Total
Course_2	Remember	2	1	0	1	1	5
	Understand	0	1	4	0	0	5
	Apply	0	2	0	1	0	3
	Count	2	4	4	2	1	13
	Percent of Questions	**15**	**31**	**31**	**15**	**8**	

Table A5 Item Analysis Details of Course Course_3

Q No	Course_3_FV	Course_3_DI	Course_3_Y
A1	0.67	0.38	84.5
A2	0.69	0.52	97.67
A3	0.66	0.46	93.02
A4	0.74	0.5	92.25
A5	0.57	0.52	91.47
A6	0.82	0.7	94.57
A7	0.51	0.26	64.34
A8	0.53	0.27	82.95
A9	0.63	0.3	86.05
A10	0.6	0.23	67.44
B1	0.66	0.43	85.27
B2	0.6	0.39	82.95
C1	0.75	0.6	94.57
C3	0.7	0.54	89.92
C5	0.68	0.53	89.92
C7	0.61	0.4	75.19

Table A6 Course Outcomes and Questions Grouping for Course_3

COs	Question Number	Actual CO Attainment
CO1	A1, A2, A3, B1	68.6
CO2	A4, C1	57.5
CO3	A5, C3	68.4
CO4	A6, A7, A8, B2	53.8
CO5	A9, C5	74.6
CO6	A10, C7	70

Table A7 Categorization of Questions of Course_3

Excellent	**1**										
	0.9										
	0.8										
	0.7									A6 (95)	
	0.6						A5 (91)	A2 (98)	C1 (95)		

								C3 (90) C5 (90)			
	0.5							A3 (93) B1 (85)	A4 (92)		
Good	**0.4**						B2 (83)	A1 (85) C7 (75)			
Fair	**0.3**						A7 (64) A8 (83) A10 (67)	A9 (86)			
Poor	**0.2**										
	0.1										
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
		Hard			**Medium**			**Easy**			

Table A8 Categorization of Questions vs Bloom's Level – Course_3

Course	Bloom's Level	Q1	Q2	Q3	Q4	Not in Quadrants	Total
Course_3	Remember	3	2	4	1	0	10
	Understand	1	1	0	0	0	2
	Apply	0	1	3	0	0	4
	Count	4	4	7	1	0	16
	Percent of Questions	**25**	**25**	**44**	**6**	**0**	