International Journal of Global Optimization and Its Application
Vol. 2, No. 1, March 2023, pp.49-59
e-ISSN: 2948-4030
https://doi.org/10.56225/ijgoia.v2i1.164

Article

Comparison in the Final Examination Questions Paper by Means of Difficulty and Discrimination Indices

Norhelyna Razali [1,*], Nuryazmin Ahmat Zainuri [1], Haliza Othman [1], Noraishikin Zulkarnain [2] and Che Nuru Saniyyati Che Mohamad Shukri [1]

[1] Centre of Research in Engineering Education and Built Environment, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia; nuryazmin@ukm.edu.my (N.A.Z), haliza@ukm.edu.my (H.O), chenurusaniyyati@ukm.edu.my (C.N.S.C.M.S)
[2] Centre for Integrated Systems Engineering and Advanced Technologies, 43600, Bangi, Selangor, Malaysia; shikinzulkarnain@ukm.edu.my (N.Z)
* Correspondence: helyna@ukm.edu.my (H.O)

Citations: Razali, N., Zainuri, N.A., Othman, H., Zulkarnain, N. & Shukri, C.N.S.C.M. (2023). Comparison in the Final Examination Questions Paper by Means of Difficulty and Discrimination Indices. *International Journal of Global Optimization and Its Application, 2*(1), 49-59.

Academic Editor: Seri Rahayu Binti Kamat.

Received: 25 December 2022 Accepted: 10 March 2023 Published: 31 March 2023

Abstract: Examination is one of the important elements in measuring the student achievement and to determine whether the course learning outcome is achieved or not. The best exam paper is the paper that can evaluate the students' achievement and thus satisfy the course learning outcome. The purpose of this study is to compare the examination papers and identify whether the course learning outcome is achieved or not based on the performance of students in the examinations. The sample is stratified according to year 1 until 4 and according to the program. The students are selected from three academic years 2015/2016, 2016/2017 and 2017/2018. The data is obtained from the marks of their mid-semester and final exams. Difficulty and discrimination indices is evaluated for each item in the exam paper. The research findings found that the ideal question for the mid-semester exam is from the session 2017/2018 with difficulty and discrimination indices range from 0.4 to 0.8. While the ideal question for final semester exam is from session 2016/2017 with difficulty index in range 0.4-0.6 and higher discrimination index as compared to other sessions. As a result, the student performance for 2017/2018 session has increased significantly in the overall assessment with 13.0% obtained grade A compared to 11.1% in 2016/2017 and only 4.9% in 2015/2016. The failure rate has also reduced at only 11.4% in 2017/2018 compared to 32.1% in 2015/2016 and 11.9% in 2016/2017.

Keywords: examination; course learning outcome; difficulty index; discrimination index.

1. Introduction

Examinations are essential and can be used to test the ability and knowledge of the students in understanding what has been taught (Jandaghi & Shaterian, 2008). Without examinations student tend not to study or probably study only the subjects or topics that they like and ignore the other subjects which they thought to be difficult although the subjects are probably very important. Examinations help the educators to deter-mine the abilities and competencies of the students and essentially be an indicator for the employers to employ them when they finish their study. Examinations can also determine whether the course outcomes (CO) have been achieved by measuring the difficulty index of each item in the exam papers. The level range between 0 to 1 and is divided into three; very difficult, moderate and very easy. The difficulty level of the questions and the student ability to answer the questions are the main factors affecting the examinations result. If the test item is too easy or too difficult, then this test fails to differ between high-achieving and low-achieving students (Zainudin et al., 2012).

Suppose this happens, then it is difficult to determine whether the course outcomes have been achieved or not. Hence, it is essential to develop exam questions that can test their ability and at the same time involve all the important elements required in exam papers (Rasul & Bukhsh, 2011). Exam questions should encompass seven areas which are, cognitive complexity, content quality, meaningfulness, language appropriateness, transfer and generalizability, fairness and reliability. The questions must involve various levels of complexity ranging from simple recall of facts to critical thinking and reasoning. Discrimination index is point biserial correlation coefficient and able to discriminate between students who performed well on the test, from those who did not. Its possible range is -1.00 to 1.00. A strong and positive correlation suggests that students who get any one question correct also have a relatively high score on the overall exam (Hingorjo & Jaleel, 2012).

Item analysis can be used to assess the quality of the exam papers and help to improve and identify biased items (Rasul & Bukhsh, 2011). Difficulty and discriminant indices are item analysis and provide useful information in terms of its validity and reliability of the constructed examination questions(Othman et al., 2015). The procedures are performed after the examination to evaluate the quality of the questions. The difficulty index is the most important component in item analysis. By determining the difficulty and discrimination indices of each question tested during the examination, the lecturer can identify between skilled and unskilled or even scored incorrectly. The difficulty and discriminant indices analysis of examination question paper can be used as a guide to improve the teaching and learning method (Wilson, 2004).

In general, most of the engineering students must fulfil several compulsory engineering mathematics courses such as Vector Calculus, Linear Algebra, Differential Equation, Engineering Statistics, and the electrical engineering students have the addition of Complex Analysis and Numerical Methods in their studies. However, research showed that engineering students in university struggle in their first-year mathematics courses (Basitere & Ivala, 2015; Hamzah et al., 2015; Wolmarans et al., 2010). In Faculty of Engineering and Built Environment (FKAB), University Kebangsaan Malaysia, an outcome-based education (OBE) has been implemented since academic year 2005/2006 to ensure the effectiveness of teaching and learning (Nor et al., 2006). The Department of Mechanical and Materials Engineering has employed the OBE approaches and the Program Out-come (PO) has been designed to fulfil the requirement of International Organization for Standardization (ISO) and Malaysian Qualifications Framework (MQF) for both programs; Mechanical and Manufacturing (Shahabudin, 2004).

PO refers to knowledge or skill that students should have mastered upon completing their studies in these programs. Mathematics is the fundamental subject in engineering and the first program outcome that the students must acquire upon graduating. However, the failure rate in engineering mathematics course is high (Zainuri et al., 2016). In order to strengthen the student's foundation in mathematics, several strategies have been done. One of it is by implementing the active learning through Cooperative Learning (CL) and Problem-Based Learning (PBL) and by integrating the e-learning with the traditional teaching method to support diverse learning style (Bhati & Song, 2019; Yamamoto et al., 2014). PBL, CL and e-learning are an active learning and is a current instructional strategy that student driven, interdisciplinary, collaborative and technology based. It allows the students to be involved in the analysis of a given project/problem and the search for possible solutions (Amamou & Cheniti-Belcadhi, 2018). This process is able to develop teamwork skills, information analysis skills, skills to teach friends, decision-making skills from data analysis and reflection skills on the ongoing learning process in terms of assessment; assignments, quizzes, tutorial and examinations are given to evaluate the students' performance (Maulana et al., 2019).

In this research, we analyze the difficulty and discrimination indices for each question/item obtained in Vector Calculus exam papers for academic year 2015/2016, 2016/2017 and 2017/2018 to investigate whether the COs are achieved and consequently fulfilled the first PO. We investigate the level of complexity for each question that contributed to the CO and finally, we present the grades obtained for the three academic years.

2. Materials and Methods

2.1. Data

The data were obtained from the mid and final semester exam marks of Engineering Mathematics I (Vector Calculus) for the first year Mechanical and Material Engineering students in three academic sessions 2015/2016, 2016/2017 and 2017/2018. There are 81 students from 2015/2016 academic session and 126 students from 2016/2017 academic session and 123 from 2017/2018 academic session involved in this study. There are 12 Programs Outcome for the Mechanical/ Manufacturing Engineering Programs and the Vector Calculus subject measures only PO1 which is on Engineering Knowledge - Ability to apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems related to mechanical engineering. There are five course outcomes for this course as shown in Table 1 and the students have 14 weeks to finish the syllabus.

Table 1. Course outcome (CO) for vector calculus course.

CO	Description(s)
CO1	Understand the basic of surfaces in space
CO2	Understand the basic concepts of partial derivatives
CO3	Understand and apply the concepts of vector function, vector field, scalar field, gradient, divergence & curl
CO4	Understand the concepts of line integral, double integral and triple integral
CO5	Able to apply Green's Theorem, Stokes' Theorem and Gauss' Theorem in solving engineering problems
CO6	Understand the concepts of differentiation and integration of complex functions

The teaching plan for the 14 weeks of study is shown in Table 2 and involve mathematical knowledge in differentiation for the first five weeks and mathematical integration in week six to week 11. The students are also introduced to the differentiation and integration of complex function at the end of the semester.

Table 2. Teaching plan with course outcome for each topic

Week	Topic	Course Outcome
1.	Surfaces in Space.	CO1
2.	Vector functions.	CO1
3.	Motion on a curve. Curvature and components of acceleration.	CO2
4.	Partial derivatives. Directional derivatives.	CO2
5.	Tangent planes and normal lines. Divergence and curl.	CO3
6.	Line integrals. Independence of path.	CO4
7.	Double integrals. Double integrals in polar coordinates.	CO4
8.	Green's theorem. Surface integrals.	CO5
9.	Stokes' theorem.	CO5
10.	Triple integrals.	CO4
11.	Gauss' theorem. Change of variables in multiple integrals.	CO5
12.	Sets in the complex plane. Functions of a complex variable	CO6
13.	Differentiation of complex functions.	CO6
14.	Integration of complex functions.	CO6

The questions for each CO are constructed based on the bloom taxonomy shown in Fig. 1 to fulfil the requirement of International Organization for Standardization (ISO) and Malaysian Qualifications Framework (MQF) in developing exam questions that can enhance competencies and potential of learners (Zainuri et al., 2016).

Figure 1. Six level in Bloom Taxonomy

Source: Nor et al. (2006)

The mid-semester exam was held after in week 8 while the final exam held after the student complete the 14 weeks of lecture. The format for the mid-semester exam papers for all sessions are descriptive and involve only CO1 and CO2. For final exam papers, there are Part A and Part B. Only questions that are compulsory to answer is used to evaluate the difficulty and discrimination indices. Table 3 shows the CO in Part A final examination paper for KKKQ1123 Vector Calculus 2015/2016 session. There are six items measuring all COs except CO5 because it is measured in Part B. Meanwhile, complete COs are measured in final examination paper in 2016/2017 session with total eight items and 2017/2018 session with 11 items as shown in Table 4 and 5 respectively.

Table 3. CO for vector calculus final examination paper 2015/2016 session.

Question Number	Course Learning Outcome (CLO)					
	1	2	3	4	5	6
Q1	×					
Q2			×			
Q3		×				
Q4			×			
Q5				×		
Q6						×

Table 4. CO for vector calculus final examination paper 2016/2017 session

Question Number		Course Outcome (CO)					
		1	2	3	4	5	6
Part A	Q1	×					
	Q2			×			
	Q3				×		
	Q4				×		
	Q5						×
Part B	Q1		×				
	Q2				×		
	Q3					×	

Table 5. CO for vector calculus final examination paper 2017/2018 session

Question Number		Course Outcome (CO)					
		1	2	3	4	5	6
Part A	Q1	×					
	Q2		×				
	Q3		×				
	Q4			×			

Question Number		Course Outcome (CO)					
		1	2	3	4	5	6
	Q5			×			
	Q6				×		
	Q7				×		
	Q8						×
Part B	Q1					×	
	Q2					×	

2.2. Difficulty and Discrimination and Indexes

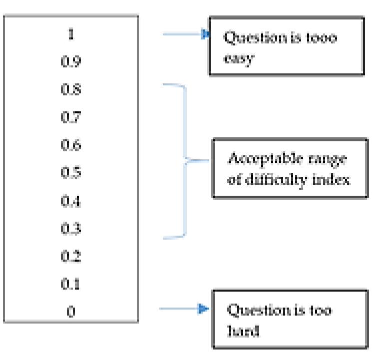
Microsoft Excel is used to compute the difficulty and discrimination indices based on the mid-semester and final semester marks. The formulas are as follow:

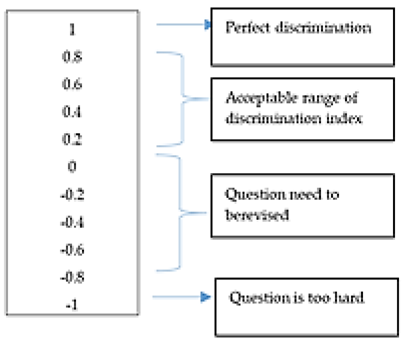
$$\text{Difficulty Index}_{\text{question}(i)} = \frac{M_{T(i)} + M_{R(i)}}{N * m_i} \tag{1}$$

and

$$\text{Discrimination Index}_{\text{question}(i)} = \frac{M_{T(i)} - M_{R(i)}}{n * m_i} \tag{2}$$

Where:
$M_{T(i)}$ = total marks of high students' performance group
$M_{g(i)}$ = total marks of low students' performance group
N = total number of students' for both groups
n = total number of students' in one group
m_2 = total marks for question *i*





3. Results

The distribution of Bloom Taxonomy in the mid-semester exam for all sessions (see Figure 2). It is shown that both 2015/2016 and 2017/2018 sessions have the same level of complexity with 30% Understanding and 20% Applying. While in 2016/2017 involve highest percentage in Understanding with 35% and lowest percentage in Applying with 15%. None of the question in all session examine the low-level Bloom Taxonomy in Remembering.

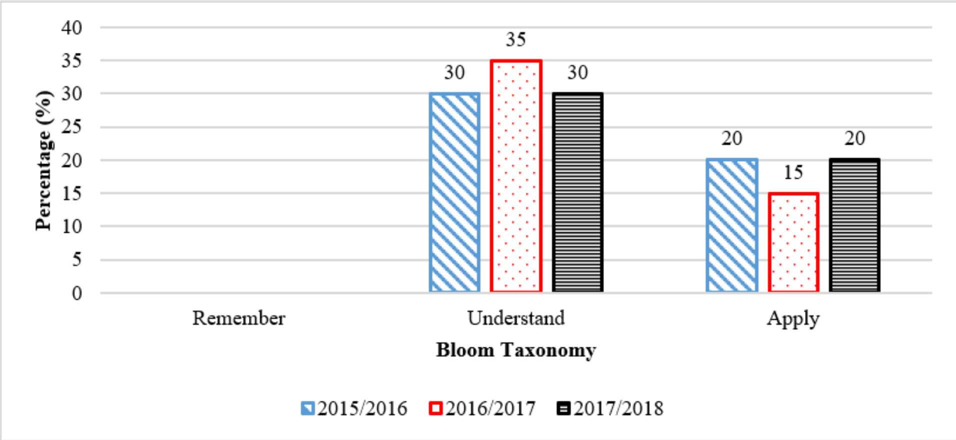


Figure 2. Percentage of bloom taxonomy in mid semester exam papers for each session

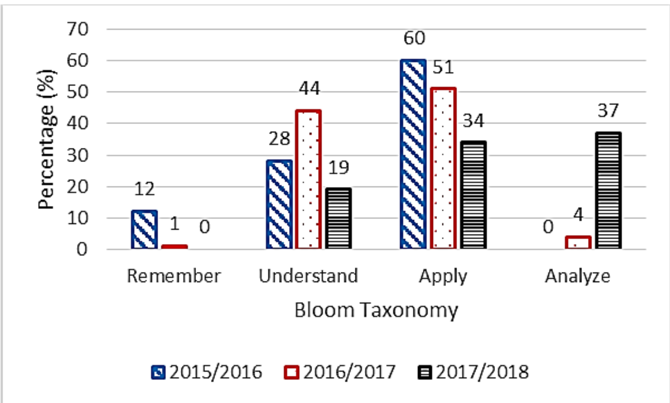


Figure 3. Percentage of bloom taxonomy in final exam papers for each session

In the final examination questions, a higher level of complexity is involved, and the students must be able to apply and analyze the knowledge they gained throughout this course. The distribution of items is higher mainly on Application level with 60% and 51% for academic session 2015/2016 and 2016/2017 respectively and Analysis level with 37% for academic session 2017/2018. It is observed that the items from academic session 2016/2017 involved a wide range of complexity from Remembering to Analyzing whereas the items from academic session 2015/2016 only test the Remembering to Application levels. The items in academic session 2017/2018 have the highest complexity in terms of its Bloom Taxonomy.

The difficulty index for Vector Calculus mid-semester examination paper is measured based on the marks from the high student's performance and the marks from low students' performance as shown in the research methodology above. Figure 4 shows the difficulty index for the mid-semester exam in all sessions. The graph that lies at the top of the figure indicates that the student finds that the question is easier to answer. Question 1 evaluate the CO1 while questions 2 and 3 evaluate the CO2 and all questions are in moderate level between 0.4 to 0.6. For question 1, it shows that the difficulty index for all sessions are about the same with about 0.5 and indicate that half of the students.

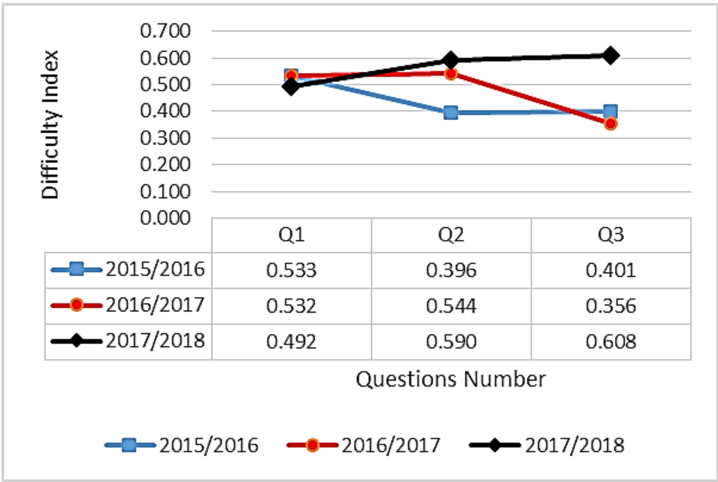


Figure 4. Difficulty index for vector calculus mid semester exam paper for each session.

For questions 2 and 3, student in academic session 2017/2018 find the questions which test CO2 are slightly easier compared to the students from the previous year. This is the graph lies at the top in Figure 4. The discrimination index for the mid-semester exam paper is shown in Figure 5. All items are in the acceptable range with question 2 and 3 are nearly perfect to discriminate the high-achiever and low-achiever for students from academic session 2017/2018.

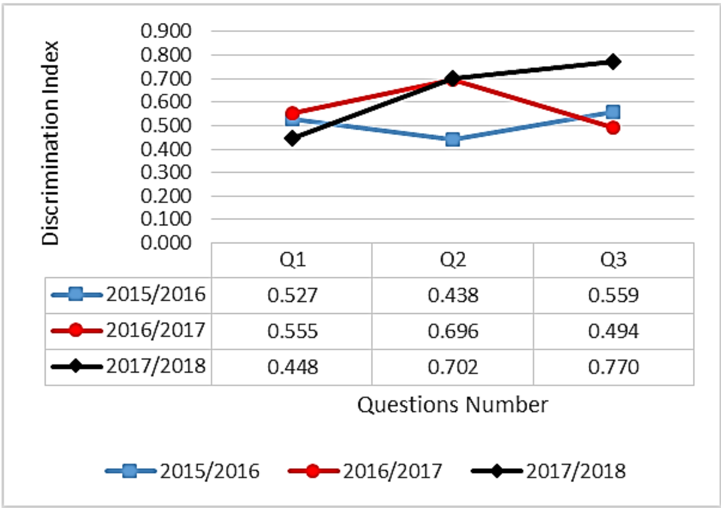


Figure 5. Discrimination index for vector calculus mid semester exam papers for each session.

In the final semester exam papers, the index for all COs are evaluated except for session 2015/2016 since the CO5 is not in the compulsory part and included only in optional Part B. For session 2016//2017 and 2017/2018, Part B is included since it is compulsory and the questions in this part have the same COs and bloom level. The difficulty and discrimination indices for each item in the final semester is evaluated and the average value for each CO is presented. In Figure 6, the difficulty index for five COs is plotted. It is observed the index values are moderate except for CO6 where the students in session 2015/2016 and 2017/2018 find it too hard with index value below moderate level with 0.258 and 0.288 respectively. It is also observed that the index value for session 2016/2017 is higher for most items namely CO1, CO3, CO5 and CO6. Overall, for the final exam items, CO2 is the easiest while CO6 is the hardest. In terms of the discrimination index, it is observed that all values are in the acceptable range and exam question in session 2016/2017 have the most items that can discriminate the score followed by the question in session 2017/2018 and lastly 2015/2016.

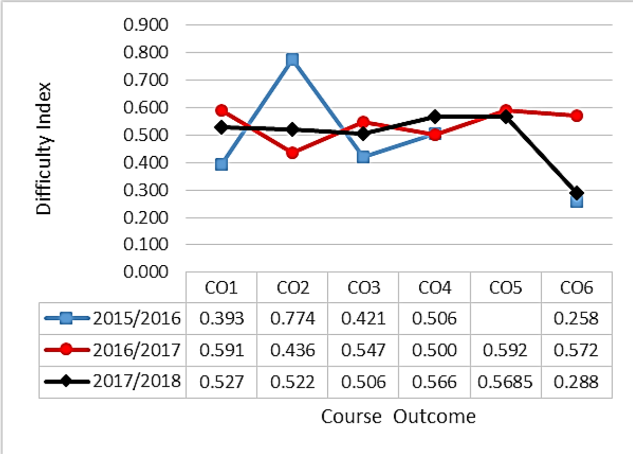


Figure 6. Difficulty index for vector calculus final exam paper for each session.

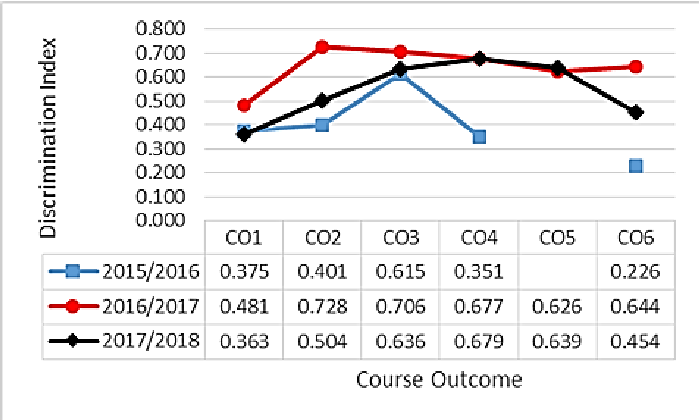


Figure 7. Discrimination index for vector calculus final exam papers for each session.

In the next two figures, we present the grade analysis for mid-semester and final semester exam papers respectively. In Figure 8 it is observed that there are significantly increased in the percentage of students who obtained good grades; A, A-, B+ and B- especially grade A with 7.4% in session 2015/2016, 2.4% in session 2016/2017 and 22.8% in session 2017/2018 in the mid-semester exam. It is also observed that significant decrease in students' grades D and E especially grade E with 48.1% in 2015/2016, decreased to 29.4% in 2016/2017 and finally to only 13.8% in 2017/2018. In the final semester exam, the same trend is observed where the student in obtained good grades increased significantly in session 2016/2017 and 2017/2018 compared to 2015/2016 for grades A, A- and B+. The failure rate is also reduced with 33.3% of students who failed in 2015/2016 reduced to 15.9% and 16.3% in both 2016/2017 and 2017/2018 respectively. The failure rate in both mid-semester and final semester exam in 2015/2016 have been reduced to about half in sessions 2016/2017 and 2017/2018.

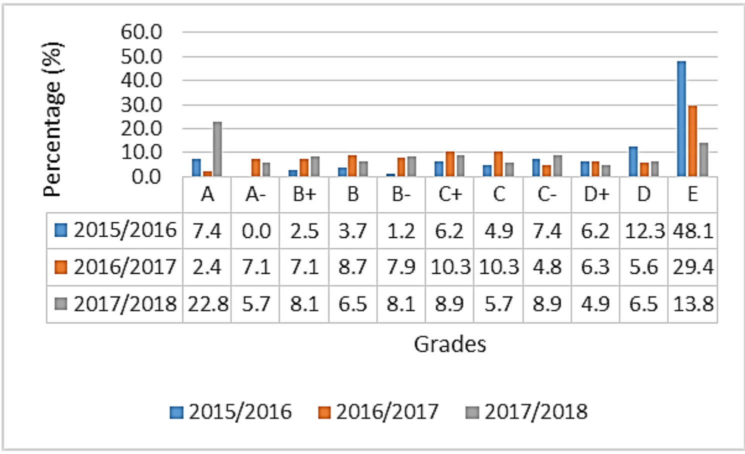


Figure 8. Percentage for mid semester examination grades.

Table 6 shows the overall assessment distribution in all sessions and Figure 10 shows the grade obtained when the continuous assessments such as quizzes, e-learning/project and cooperative learning marks are calculated. It is observed that students in session 2017/2018 obtained the highest percentage in grades A, A- and B+ and have the lowest percentage in grades C+ to E. It is observed that when the continuous assessment is considered, the grades obtained in session 2017/2018 is the best followed by sessions 2016/2017 and 2015/2016.

Table 6. Assessment distribution for each session

Assessment	Percentage (%)		
	2015/2016	2016/2017	2017/2018
Quiz	15	10	10
E-learning/Project	5	10	10
Cooperative Learning	10	10	10
Mid Semester	20	20	20
Final	50	50	50

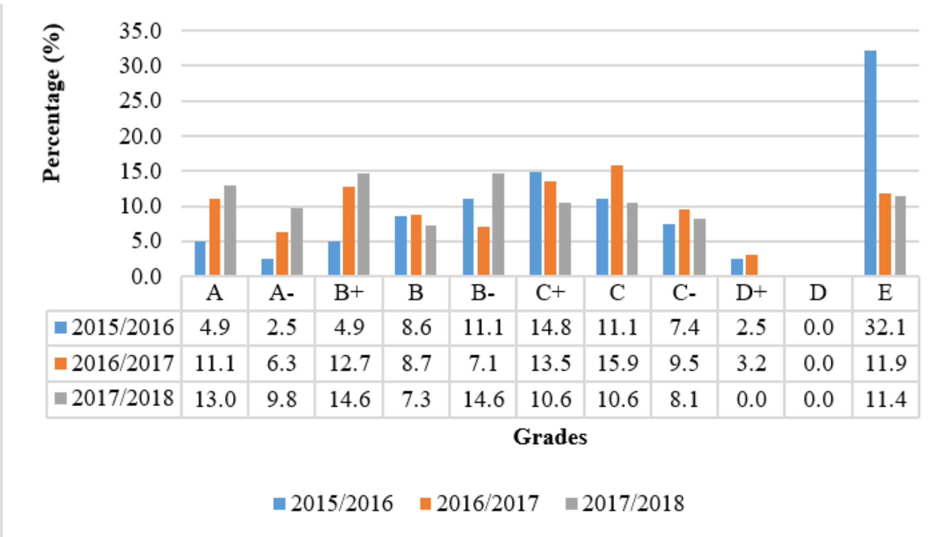


Figure 9. Overall percentage for vector calculus examination grades

4. Conclusions

The examination has been used to evaluate students' performance since school. Hence, it is important to develop and construct an exam paper that will enhance the understanding and the ability to apply knowledge and skills to a high level. It is not easy to construct such questions, especially for mathematics. The idea of choosing a moderately difficult question is to give a fair evaluation to the high and low-achieving students and to investigate whether the course outcome is achieved. Based on the item analyses in the mid-semester exam, the academic session 2017/2018 have the ideal difficulty and discrimination indices and it is shown in the grade obtained. Whereas in the final exam paper, the academic session 2016/2017 have the ideal difficulty and discrimination indices. The questions in sessions 2016/2017 and 2017/2018 are not only ideal but involved a higher level of bloom taxonomy as compared to the previous session. In this research, we have seen the improvement made for Vector Calculus final exam paper especially in session 2016/2017 and 2017/2018. The difficulty level is moderated and give positive impact to the students' performance. We can conclude that the course outcome is achieved based on the difficulty index and this can guide us in constructing better questions for the students and reduce the percentage of failure. It is of interest to develop a model that is able to determine the quality of question/item before the exam is held and the grade is obtained in order to help students in understanding Vector Calculus better and thus fulfil the course outcome and shown in their final exam results.

Author Contributions: Conceptualization, N.R. and N.A.Z.; methodology, N.R.; software, N.Z.; validation, N.A.Z., H.O., N.Z. and C.N.S.C.M.S.; formal analysis, N.R.; investigation, N.R.; resources, N.R.; data curation, N.A.Z., H.O., N.Z. and C.N.S.C.M.S.; writing—original draft preparation, N.R. and N.A.Z.; writing—review and editing, N.R., N.A.Z., H.O., N.Z. and C.N.S.C.M.S.; visualization, H.O.; supervision, N.A.Z., H.O., N.Z. and C.N.S.C.M.S.; project administration, N.A.Z.; funding acquisition, N.A.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank to the Universiti Kebangsaan Malaysia for supporting this research and publication. Also, the author would like to thank the reviewers for all their constructive comments.

Conflicts of Interest: The authors declare no conflict of interest.

References

Amamou, S., & Cheniti-Belcadhi, L. (2018). Tutoring in project-based learning. *Procedia Computer Science*, *126*, 176–185.

Basitere, M., & Ivala, E. (2015). Mitigating the mathematical knowledge gap between high school and first year university chemical engineering mathematics course. *Electronic Journal of E-Learning*, *13*(2), pp68-83.

Bhati, A., & Song, I. (2019). New methods for collaborative experiential learning to provide personalised formative assessment. *International Journal of Emerging Technologies in Learning*, *14*, 179–195.

Hamzah, F. M., Kamarulzaman, P. S. D., Ismail, N. A., & Jafar, K. (2015). Student's performance in engineering mathematics courses: Vector Calculus versus Differential Equations. *Journal of Engineering Science and Technology Special Issue on UKM Teaching and Learning Congress 2013*, 91–97.

Hingorjo, M. R., & Jaleel, F. (2012). Analysis of one-best MCQs: the difficulty index, discrimination index and distractor efficiency. *JPMA-Journal of the Pakistan Medical Association*, *62*(2), 142–147.

Jandaghi, G., & Shaterian, F. (2008). Validity, Reliability and Difficulty Indices for Instructor-Built Exam Questions. *Journal of Applied Quantitative Methods*, *3*(2), 151–155.

Maulana, I. T., Hary, R. D., Purwasih, R., Firdian, F., Sundara, T., & Na'am, J. (2019). Project-Based Learning Model Practicality on Local Network Devices Installation Subject. *International Journal of Emerging Technologies in Learning*, *14*(15), 94–106. https://doi.org/10.3991/ijet.v14i15.10305

Nor, M. J. M., Hamzah, N., Basri, H., & Badaruzzaman, W. H. W. (2006). Pembelajaran berasaskan hasil: Prinsip dan cabaran. *Pascasidang Seminar Pengajaran Dan Pembelajaran 2005*, 54–62.

Othman, H., Ismail, N. A., Asshaari, I., Hamzah, F. M., & Nopiah, Z. M. (2015). Application of Rasch measurement model for reliability measurement instrument in vector calculus course. *Journal of Engineering Science and Technology*, *10*(2), 77–83.

Rasul, S., & Bukhsh, Q. (2011). A study of factors affecting students' performance in examination at university level. *Procedia-Social and Behavioral Sciences*, *15*, 2042–2047. https://doi.org/10.1016/j.sbspro.2011.04.050

Shahabudin, S. H. (2004). The Malaysian Qualifications Framework. In *EAHEP Roundtable on QF, 1-3 July 2009 Brussels*. MAPCU National Conference.

Wilson, M. (2004). *Constructing measures: An item response modeling approach*. Routledge.

Wolmarans, N., Smit, R., Collier-Reed, B., & Leather, H. (2010). Addressing concerns with NCS: An analysis of first-year student performance in mathematics and physics. *Science and Technology Education*, *2*, 274–284.

Yamamoto, H., Nakayama, M., & Shimizu, Y. (2014). Measures to Promote Practice of Quiz and Evaluation Thereof in Blended-Learning. *International Journal of Emerging Technologies in Learning (Online)*, *9*(5), 32–39. https://doi.org/10.3991/ijet.v9i5.3854

Zainudin, S., Ahmad, K., Ali, N. M., & Zainal, N. F. A. (2012). Determining course outcomes achievement through examination difficulty index measurement. *Procedia-Social and Behavioral Sciences*, *59*, 270–276. https://doi.org/10.1016/j.sbspro.2012.09.275

Zainuri, N. A., Asshaari, I., Ariff, F. H. M., Razali, N., Othman, H., Hamzah, F. M., & Nopiah, Z. M. (2016). Item analysis for final exam questions of engineering mathematics course (Vector calculus) in UKM. *Journal of Engineering Science and Technology*, *11*, 53–60.