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Integration Performance in Intermediate Calculus Course at Diploma Level in the East Coast of Malaysia

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Authors' contributions

This work was produced through collaboration between all authors. Author SU performed the statistical analysis and wrote the most parts of the manuscripts. Author NR gathered all literature and performed the analysis of performance according to questions. Authors NHMA, NM and RM gathered the materials and data as well as given valuable inputs into analysis. All authors read and approved the final manuscript.

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Abstract

Aims: Calculus course plays an important role in the success of science and technology as it compounds knowledge, performances and understanding developed in the fundamental stages for other mathematical, science and technology courses. Previous studies claimed that integration is a difficult topic as compared to the other topics in Calculus course. However, studies on how far the integration performance contributes to the overall performance of the subject itself are remained unanswered. Thus the objective of this study is to investigate the relationship between students' integration performance with their performance in Intermediate Calculus (known as Calculus I) course.
Place and Duration of Study: 676 students' examination papers from two consecutive semesters for

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year 2016 at the Diploma level in one higher institution in the East Coast of Malaysia were analyzed in this study. Marks obtained from each question were used as the performance indicator.
Methodology: The descriptive analysis was used to compare the performance of two consecutive semesters of students in their final exam for Calculus I. The students who scored less than half of 33 marks (less than 16.5) in integration topic were deemed as having low integration performance. Otherwise they were considered as having high integration performance. By using the cross-tabulation and Chi-Square correlation, the relationship between the scores obtained in integration topic and final examination results were investigated.
Results: The findings revealed students with low integration performance have high tendencies to fail the final examination and students with high integration performance have more chances to pass the final examination. In addition, the result showed that more than half of the repeaters have the tendency to fail the course again. Meanwhile, the result also showed that students who remained weak in the previously taught concept were also unable to solve the problem posed to them in the integration topic. Based on the findings of the study, it is recommended that educators need to plan effective strategies such as organizing the diagnostic test at prior to the Calculus class, promoting actively the mathematics clinic, organizing workshop for the diagnosed weak students or peer group discussion, and sharing materials with the students through the online learning platform.

Keywords: Calculus; integration; repeaters; performance.

1 Introduction

Mathematical performances play a crucial role in the success of careers in the field such as science, technology, engineering and mathematics [1]. However, since the last twenty years ago, mathematics teaching and learning process has faced big issues at all level of education due to the lower achievement in mathematics course. Many parties which involving parents, students, teachers, universities, education department, and Ministry of Education are concerned about the performance of students who are poor in Mathematics and the declining of the mathematical readiness of students enrolling in the mathematics course.

Mathematics consists of various branches such as Algebra, Calculus, Trigonometry and Geometry. Among the above-mentioned branches of mathematics, Calculus is the upmost importance in mathematics as it compounds knowledge, performances and understanding developed in the fundamental stages of other mathematical and science courses [2]. Although the Calculus course is obviously seen to be taught at the college or university level, but the basic of the course has been introduced to the students as early as during the secondary level.

Previous studies have discussed on various issues in Calculus and ways that have been implemented in improving the performance of Calculus course. A study by [3] showed that there is a strong relationship between the performance of mathematics and additional mathematics course in Malaysian Certificate of Education (MCE) with the Calculus course at the university level. This is obviously related since one of the sub-topics in additional mathematics is on basic Calculus. According to [4] some mathematics courses such as Pre-Calculus, Calculus I, Mathematics II and Engineering Mathematics are categorized as underachieved courses with the additional mathematics subject at MCE level become a good predictor for all the mathematics courses.

In other studies, [5] claimed that Calculus has minor impact on the students' performance at year four degree in Information Technology Management in the Business Faculty at Ryerson University. Meanwhile, Hamzah et al.'s [6] studied on engineering students found that Calculus and differential equation courses have positive linear relationship. This is due to the topics covered in Calculus which are differentiation and integration needed to be known earlier before learning differential equation. Recently, [7] found that there is

a strong relationship between Calculus achievement and student performance in electrical and electronics engineering courses. This is due to the problem solving in engineering courses requires good understanding of Calculus and this shows that a strong foundation in Calculus is required in order to achieve good grades in electrical engineering courses.

In Malaysia, the exposure into Calculus's sub-topic such as properties of differentiation and integration were made as early as the secondary school level. Differentiation is defined as an algorithm process which can be achieved by analyzing the function definition and applying the appropriate rules to each step of the definitions [8]. It is possible to differentiate any functions however complicated it is. Conversely, integration is not an algorithmic process but it requires experience to determine which technique is suitable to anti-differentiate the integrand. Therefore, in-depth understanding of fundamental concept and performances in the framework are needed in order to master the integration topic. [9] also considered integration as a more difficult topic by students as it is the reverse process of differentiation. This study intends to focus more on the influence of integration performance on the overall performance in Calculus.

There are cases where students fail to score in Calculus even though as aforementioned, the basic of the Calculus was thought in school prior the tertiary level. As [10] stated that it is quite perplexing when some of the students who managed to pass all the necessary prerequisite to enter college still showing the sign of weakness in Calculus when they repeatedly failed the course. [11] had discussed generally about 20% to 50% rate of dropouts students came from those who repeats the same course as compared to who does not. This shows the idea of repeating subject or grade, and [12] also stated that the performance of those who repeats is lower than non-repeaters.

[13] Demonstrated that mere repetition of a class or grade was neither therapeutic nor advantageous unless factors that disable learning were identified and addressed. Hence in this study instead of taking a general focus on Calculus, the main area of concerned is in identifying the relationship between the students' integration performance and status of enrolment against their performance in Calculus. Then, rigorous descriptive analysis was carried out on the scores obtained by students on integration questions. Later, the result of the analysis is used to indicate which part of the performance need to be refined and polished as a remedial thus to lower the failure rates in Calculus.

1.1 Research hypotheses

Although many studies have been conducted on the issues related to the performance of Calculus course, but there is lack of studies focus on the contribution of a particular topic to the performance in Calculus course. The previous researchers have claimed that integration is a difficult topic compared to others but how far thus the integration performance contributes to the performance of the subject itself is still unclear. In this paper, the objectives of the study are to check relationship between students' integration performance with their status of enrolment and performance in Calculus. The hypotheses for Chi-Square correlation analyses are as follow:

1. **H_0:** There is no relationship exist between students' integration performance and their status of enrolment.

   H_1: There is a relationship exist between students' integration performance and their status enrolment.
2. **H_0:** There is no relationship exist between students' integration performance and performance in Calculus.

   H_1: There is a relationship exist between students' integration performance and performance in Calculus.

2 Research Methodology

2.1 Scope of study

Only integration marks from the final exams was used to investigate all of the students performances in integration. As this study only concern to identify whether performance in integration related to their performance in Calculus subject. This study also attempt to identify type of integration questions that most of students having difficulty in scoring higher mark. Only two final examination semester involved in this study, March and September 2016.

2.2 Participants

The subject of this study is a total of 676 students from three Science based programs of a higher education institution in the East Coast of Malaysia who learnt Calculus as part of academic curriculum to fulfil the requirement to be awarded with Diploma certificate. From this number of students, 225 of them sat for the final examination for the course titled Calculus I in March 2016 semester. The other 421 students sat for the final examination of the same course in October 2016 semester.

Being the intermediate level Calculus course, Calculus I covers the topics on limits, differentiation and integration. The integration topic is further divided into sub topics which are (i) indefinite and definite integral using basic integration formula for polynomials, trigonometric, logarithmic and exponential functions (ii) indefinite and definite integral using substitution method for polynomials, trigonometric, logarithmic and exponential functions (iii) Fundamental Theorem of Calculus (FTC) Part 1 and 2 (iv) area between curves and (v) volumes by disks, Washer and Shells method.

2.3 Procedures and instrument

The final examination paper for Calculus I was organized in such a way that it consists of five questions from all the topics. The distribution of marks of 20% goes to the questions on the limits, 47% goes to differentiation and 33% goes to integration topic. From the distribution pattern, it is shown that one-third of the marks go to the integration related question. The integration topics are categorized into three types of question. The first category of question is related to solving the indefinite and definite integral for polynomials, trigonometric, logarithmic and exponential functions using appropriate technique. The second category of question is related to FTC and the final category question is on the application of the integration itself.

The marks which obtained from each question were used as the performance indicator. The descriptive analysis was also used to compare the performance of two consecutive semesters of students in their final exam for Calculus I. A thorough descriptive analysis was also carried out in order to compare the performance of the students who had enrolled this course for the first time with those who are not the first timer for the two consecutive semesters. The marks for the integration topic were later analysed to determine how much the contribution of the integration topic towards the overall performance in Calculus I. A sum of 33 marks out of the total 100 marks was allocated to measure the students' integration performance. In this study, the students who scored less than half of 33 marks (less than 16.5) in integration topic were deemed as having low integration performance. If they scored more than 16.5, they were considered as having high integration performance. By using the cross-tabulation and Chi-Square correlation, the relationship between the scores obtained in integration topic and final examination results were investigated. The marks obtained for each integration question were compared and analysed.

3 Results

3.1 Analyses on overall performance in calculus

Table 1 describes the final examination result for Calculus I course for semester March 2016 and October 2016.

Table 1. Final examination result of Calculus I for Semester March 2016 and October 2016

Semester	Final examination result for Calculus I				Total
	Pass		Fail		
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	
March 2016	162	64	93	36	255
October 2016	362	86	59	14	421

Based on Table 1 above, about 14% from 421 students who took Calculus I in semester October 2016, failed their final examination, meanwhile 36% was reported failed for the same course for semester March 2016. There is a distinguished difference on the failure rates found between semester October 2016 and March 2016. The number of students who are not freshly enrolled for the first time is more in the class of semester March 2016. The table also shows that the failure rate is higher for this batch of students.

In order to be awarded with a diploma related to their field of studies, students must have pass Calculus I. If they failed, there is a requirement for them to re-enroll for the same course up to third attempts. Once the students failed the course for the first time, it shows that they are not competent in Calculus. Hence, if the current semester has more students re-enroll for the same course, then the overall final examination results will be affected and have higher failure rates. The differences in the types of students will be discussed further in Table 2.

Table 2. Final examination result for first timer and repeaters

Final examination set	Calculus I results								Total (n)
	First timer				Repeaters				
	Pass		Fail		Pass		Fail		
	n	%	N	%	n	%	N	%	
March 2016	122	48	29	11	40	16	64	25	255
October 2016	349	83	45	11	13	3	14	3	421
Total	471	70	74	11	53	8	78	11	676

Based on Table 2, it is reported that the number of students who took this course repeatedly for March 2016 and October 2016 are 104 and 27 respectively which is about 41% and 6% of the total students. This shows that even though the number of failure in the March 2016 final examination is quite high (93) but, only 27 students that is 29% of the total of students repeated the course in the consecutive semester. This is due to the fact that some of the students might have dropped the course. It is an advantage for the students to register the same course in the consecutive semester since the knowledge and performance are still fresh compared to when they take the course in the following semester.

The percentage of failure for students who freshly registered for Calculus I is 11% for both March and October 2016. Based on the data presented in Table 2, 62% (64/104) of those who repeated the course for March 2016 failed the final examination again. Meanwhile, 52% of the repeaters failed again for October 2016. This shows that for two consecutive semesters more than 50% repeaters failed the same course. Thus, extra attention need to be taken by the students, parents and university and new method must be adopted in order to help them succeed in the course.

In order to check whether integration performance related to the students' status, cross tabulation table and correlation analysis were done. The result as in Table 3, shows the details on comparison between students' status and their integration performance.

Table 3. Cross tabulation table for integration performance and status

		Integration performance		Total
		High	**Low**	
Status	Fresh	405	140	545
	Repeater	43	88	131
Total		448	228	676

Based on Table 3, only 33% (43/131) of the students scored more than 16.5 marks in the integration topic are repeaters, thus it is rated as highly performed compared to about 75% students with high integration performance are recorded from fresh students. Further analysis to check whether integration performance really related to students' status was checked using the Chi-square analysis.

Table 4. Chi-square test analysis for integration performance and status

	Value	**df**	**Asymptotic significance (2-sided)**
Pearson Chi-square	81.327[a]	1	.00

As reported in Table 4, the value for Pearson's Chi Square is 81.327 with p-value less than 0.000 shows that there is a relationship between integration performance and their status as repeaters or fresh student. Therefore, based on the results from cross-tabulation table and Chi-square test, the difference in the students' integration performance is related to students' status. Hence, this might actually cause the student to repeat the subject if they had low integration performance. Therefore, the relationship whether integration performance really can affect significantly their Calculus performance will be checked to confirm this.

As mentioned earlier, the integration topic in both March and October 2016 examination make up to 33 marks out of total 100. The students who scored less than half of 33 marks (less than 16.5) in integration topic were deemed as having low integration performance. If they scored more than 16.5, they were considered as having high integration performance. Table 5 shows the proportion of students' integration performance based on the final examination results for both semesters.

Table 5. Proportion of students' integration performances based on final examination result

		Type of integration performance				Total	
		High		**Low**			
Final examination results	Fail	11	2.5%	141	61.8%	152	22.5%
	Pass	437	97.5%	87	38.2%	524	77.5%
Total		448	100.0%	228	100.0%	676	100.0%

Based on Table 5, only 2.5% of the students rated as highly performed (scored more than 16.5 marks in the integration topic) failed the final examination. Meanwhile, 61.8% students with low integration performance failed the final examination. Besides, 97.5% students rated as highly performed pass the final examination and 38.2% students with low integration performance pass the final examination. This represents the students with low integration performance have more tendency to fail the final examination and students with high integration performance have more chances to pass the final examination.

The value for Pearson's Chi Square is 305.746 with p-value less than 0.00 shows that there is a relationship between the score in the integration topic and the performance in Calculus course. Fig. 1 shows the bar chart of integration performance and performance in Calculus I.

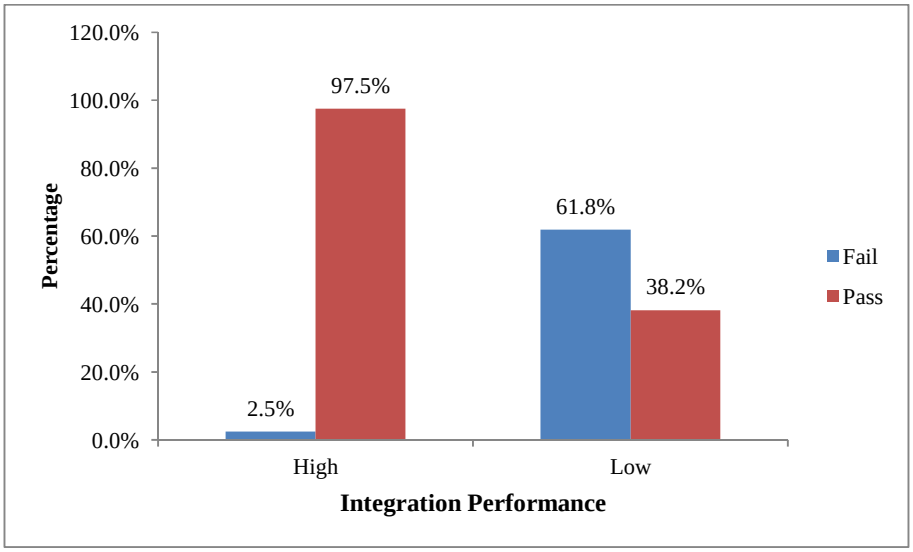


Fig. 1. Bar chart of integration performance and performance in Calculus I

Based on Fig. 1, students who have high integration performance are 97.5% more likely to pass Calculus I. Meanwhile, students with low integration performance are 61.8% more likely to fail the course. Therefore, the odd ratio and Chi square correlation suggest that integration performance does have significant influence in the Calculus I performance.

3.2 Analysis of performance based on type of integration problems

As mentioned earlier, there are three types of questions which are Category 1, question-related to solve the indefinite and definite integral for polynomials, trigonometric, logarithmic and exponential functions using appropriate technique, Category 2, question-related to FTC and Category 3, question on the application of integration. Table 6 shows number of questions and total marks for each category for both semesters.

Table 6. Number of questions and total marks for each category for Semester March 2016 and October 2016

Type of questions	No of question	Question	Mark for each question
Category 1	3	Q1C1, Q2C1, Q3C1	4, 5, 4
Category 2	1	Q1C2	4
Category 3	3	Q1C3, Q2C3, Q3C3	6, 5, 5

The three questions for Category 1 are represented with Q1C1, Q2C1, Q3C1 and have 4, 5, 4 marks respectively as shown in Table 7.

Figs. 2, 3 and 4 show the percentage obtained based on marks for Q1C1, Q2C1 and Q3C1 respectively.

Q1C1 in semester March 2016 involved indefinite integral using direct method whereby students need to expand the function, do the multiplication and finally integrate the function using power rule. While for October 2016, the question is related to solve the indefinite integral for rational function using substitution method. Fig. 2 shows that about 65% and 25% students failed to solve the problem with 53% and 14% got zero marks for March 2016 and October 2016 respectively. Based on March 2016, the students were weak to solve the basic integral question. As Q1C1 in March 2016 involved expanding the function and indices

operation, the students still had problems in basic concept of algebra. For October 2016, basically the students were able to choose the correct substitution but were not able to integrate the rational function.

Table 7. Questions in Category 1

Question	March 2016	October 2016	Full marks
Q1C1	$\int t^{\frac{1}{2}}(t-1)^2\,dt$	$\int \frac{6}{5(4-7x)^3}\,dx$	4
Q2C1	$\int \frac{\sin x}{(1+\cos x)^3}\,dx$	$\int \tan^3 4x \sec^2 4x\,dx$	5
Q3C1	Given $f(x)=\begin{cases} 2x+3, & x\le 0 \\ x^3, & x>0 \end{cases}$ Find the value of k if $\int_{-1}^{4} k\,f(x)\,dx = 33$	$\int_2^5 \left(x+\frac{2}{x}\right)^2 dx$	4

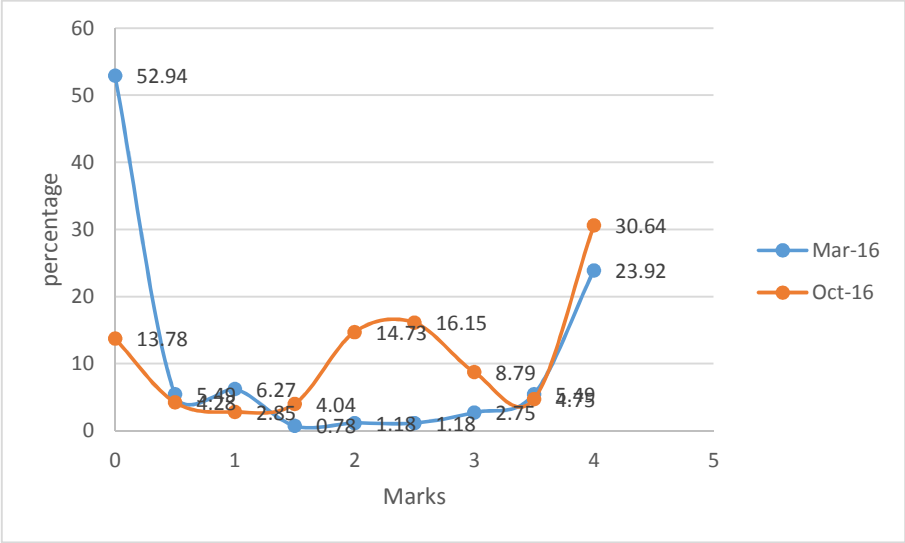


Fig. 2. Percentage obtained based on marks for Q1C1

Q2C1 in both semesters are related to solve the indefinite integral for trigonometric function using substitution method. Fig. 3 shows that about 32% and 63% students failed to solve the problem with 24% and 40% got zero marks for March 2016 and October 2016 respectively. This shows that the students still did not master the substitution method in solving the question especially when related to trigonometric function in composite form. It is easier to differentiate tan x but when it comes to tan $4x$, sometimes the students did careless mistakes and did not consider the differentiation for $4x$. This leads to the higher failure rate for Q2C1 in October 2016.

Q3C1 in semester March 2016 involved the properties of definite integral for piece wise function. While for October 2016, the question on solving the definite integral of polynomial and rational functions. Fig. 4

shows that 92% and 31% students failed to solve the problem with 32% and 16% got zero marks for March 2016 and October 2016. This shows that the students were very weak in solving the definite integral especially when involved the properties of definite integral and piece wise function.

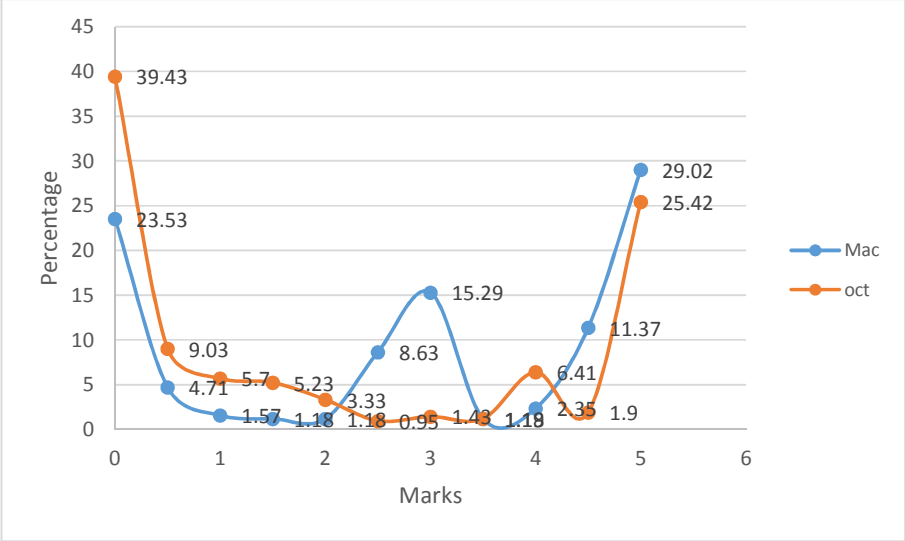


Fig. 3. Percentage obtained based on marks for Q2C1

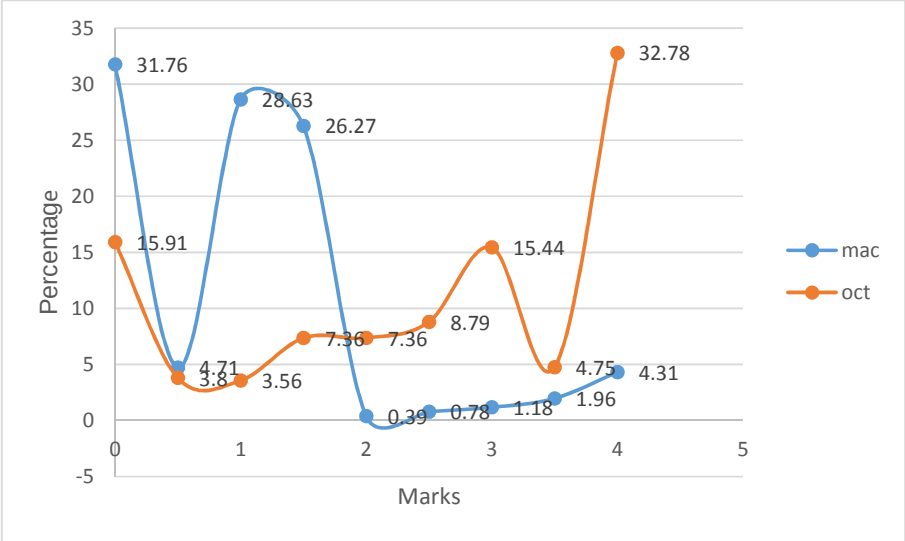


Fig. 4. Percentage obtained based on marks for Q3C1

The question for Category 2 is represented with Q1C2 with 4 marks as shown in Table 8.

Fig. 5 shows the percentage obtained based on marks for Q1C2.

Q1C2 in both semesters are related to solve the second fundamental theorem of Calculus. Fig. 5 shows that about 49% and 21% students failed to solve the problem with 17% and 7% got zero marks for March 2016

and October 2016 respectively. For March 2016, the clue to solve the question was given as shown in Table 8. However, the clue given is in a basic form of the second fundamental theorem of Calculus. Students need to extend the clue to the composite form but many students used the clue directly which led to the quite high failure rate.

Table 8. Questions in Category 2

Question	March 2016	October 2016	Full marks
Q1C2	$F(x) = \int_0^{x^4} \sqrt{t}\ dt$. Find i) $F'(x)$ ii) $F'(1)$ Hint: $\frac{d}{dx}\int_a^x f(t)\,dt = f(x)$	Given $F(x) = \int_0^{\sqrt{x}} \frac{t}{t^2-1}\ dt$ Use the second Fundamental Theorem of Calculus to find i) $F'(x)$ ii) $F'(3)$	4

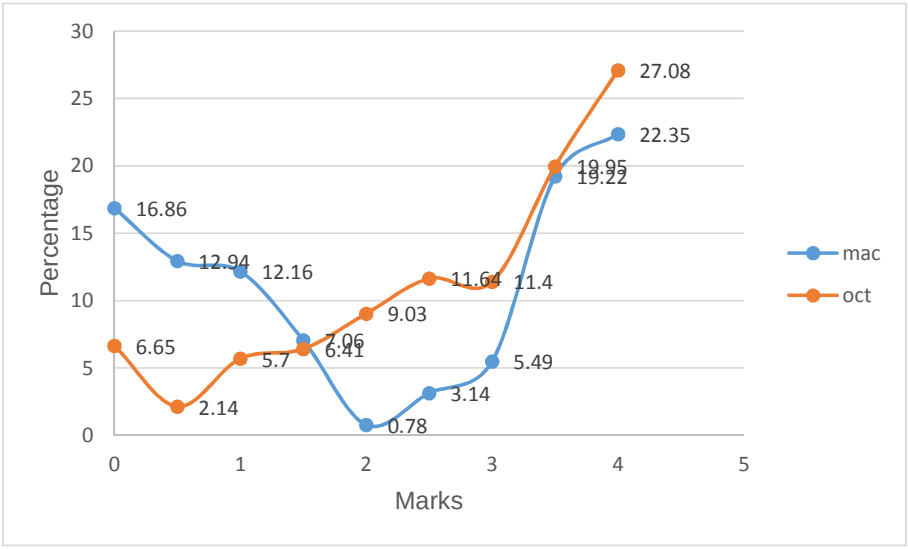


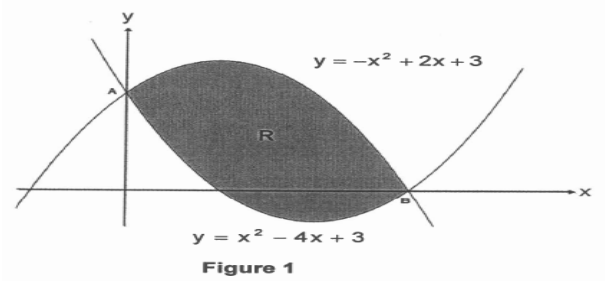
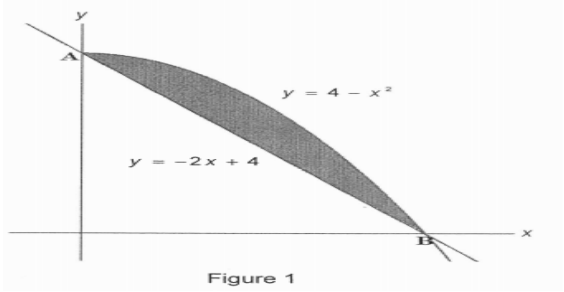
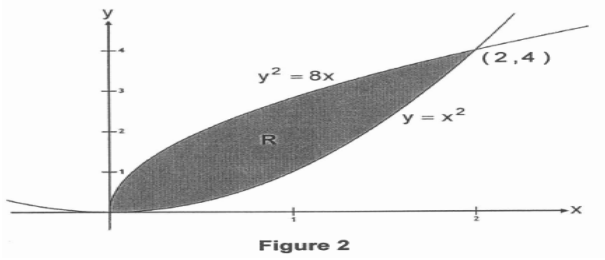
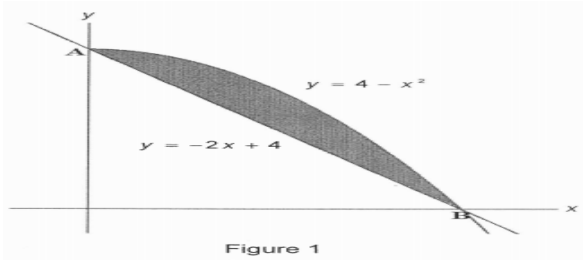
Fig. 5. Percentage obtained based on marks for Q1C2

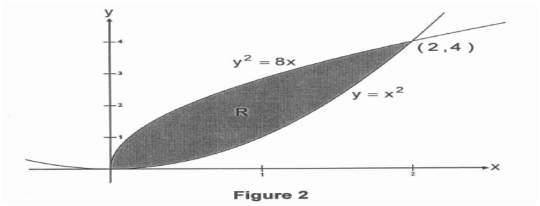
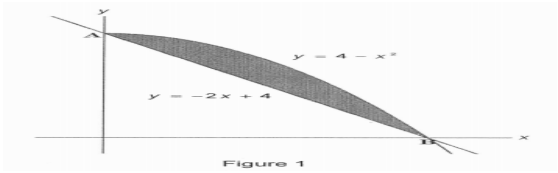
The three questions for Category 3 are represented with Q1C3, Q2C3, Q3C3 and have 6, 5, 5 marks respectively as shown in Table 9.

Figs. 6, 7 and 8 show the percentage obtained for Q1C3, Q2C3 and Q3C3 and have 6, 5 and 5 marks respectively.

Q1C3 in both semesters are related to solve the simultaneous equations and to find the area of the respective region. The functions involved are polynomial. The students did well for this question. However, October 2016 shows a better performance compared to March 2016. About 13% and 4% students failed to solve the problem with about 5% and 1% got zero marks for March 2016 and October 2016 respectively.

Table 9. Questions in Category 3

Question	March 2016	October 2016	Full marks
Q1C3	Figure below shows 2 curves intersect at point A and B.  Figure 1 i) Find the coordinates of A and B ii) Find the area of the shaded region R	The shaded region in Figure below is enclosed by two curves as shown  Figure 1 a) Find the coordinates of A and B b) Find the area of the shaded region	6
Q2C3	Consider the region R enclosed by the two curves as shown in Figure below  Figure 2 Find the volume of the solid generated by revolving R i) about $x = 0$ using Washer Method	The shaded region in Figure below is enclosed by two curves as shown  Figure 1 i) Set up the integral to find the volume of the solid obtained when the shaded region is revolved about $y = 0$	5

Question	March 2016	October 2016	Full marks
Q3C3	 Figure 2 Find the volume of the solid generated by revolving R: i) about $y = 0$ using Shell Method	 Figure 1 i) Find the volume of the solid using Shell Method when the shaded region is revolved about the line $x = 2$	5

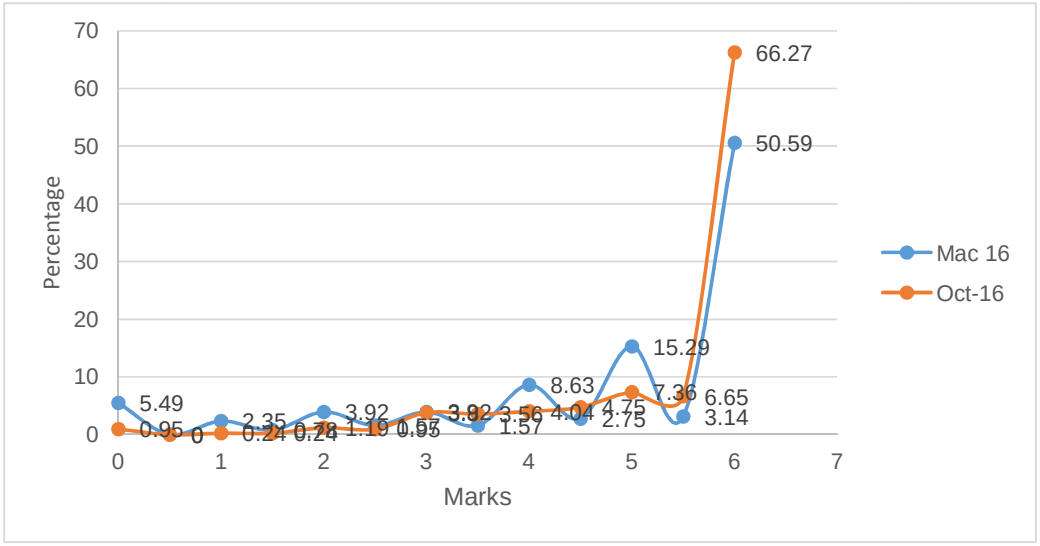


Fig. 6. Percentage obtained based on marks for Q1C3

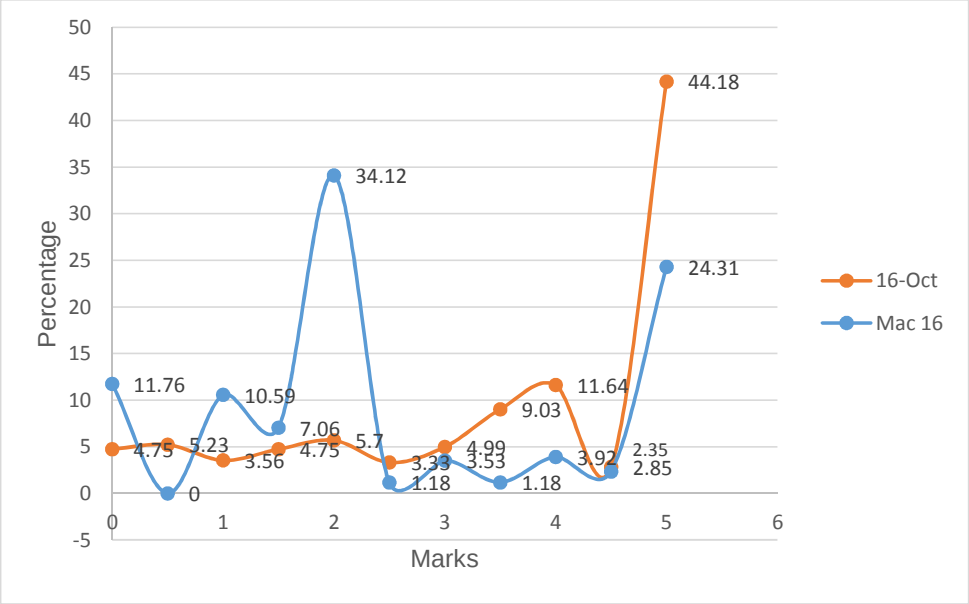


Fig. 7. Percentage obtained based on marks for Q2C3

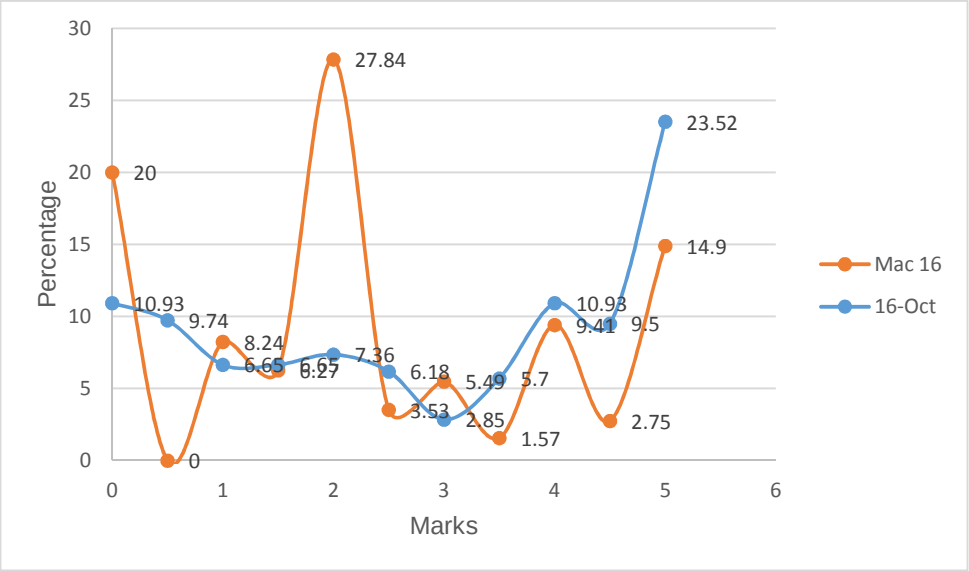


Fig. 8. Percentage obtained based on marks for Q3C3

Q2C3 and Q3C3 are applications problem on evaluating the volume using Washer's and Shell methods respectively. Students were equally unable to solve the problems completely. For Q2C3, about 64% and 24% students failed to solve the problems with 12% and 5% got zero marks for March 2016 and October 2016 respectively. Similarly, Q3C3 shows the same pattern whereby 62% and 41% students failed to solve the problem with 20% and 11% got zero marks for March 2016 and October 2016 respectively. The students may get half of the mark if they managed to set up the integrals and failed to get full mark when they unable to solve the integrals correctly.

4 Discussion

Table 10 summarizes the performance based on types of Integration problems. Almost for all questions (except for Q2C1), the performance for October 2016 is better compared to March 2016. The result for Q1C1 portrays that students were still weak in basic concept of algebra. Similarly, the result for Q2C1 shows that students were still not able to get good grasp on the trigonometric differentiation concept. Meanwhile, the result for Q3C1 shows that the students did not have the adequate performances needed to solve definite integral. The result for Q1C2 shows that students were still have problems in solving derivative of composite function. The results for Q2C3 and Q3C3 show that the students were not fully understand the concept of Washer's and Shell method. This result shows that students were still weak in the previous concept taught which caused the inability to solve the problem posed to them in the integration topic.

Table 10. Summary of performance based on types of integration problems

Category	Questions	Fail (%)		Zero marks (%)	
		March 2016	Oct 2016	March 2016	Oct 2016
	Q1C1	65	25	53	14
Category 1	Q2C1	32	63	24	40
	Q3C1				
Category 2	Q1C2	49	21	17	7
	Q1C3	13	4	5	1
Category 3	Q2C3	64	24	12	5
	Q3C3	62	41	20	11

5 Conclusion

The percentage of the failure rates for October and March 2016 are 14% and 36% respectively. The difference on the failure rates was found due to the different status of students who enroll on these semesters. The number of students who is not freshly enrolled for the first time is more in the batch of semester March 2016. Thus, the failure rate is higher for this batch of students.

Separately based on the status of students, the failure rates for students who freshly registered for Calculus I is 11% for both March and October 2016. However, 62% of those who repeat the course for March 2016 failed the final examination again. Meanwhile, 52% of the repeaters failed again for October 2016. This shows that for two consecutive semesters more than 50% repeaters have the tendency to fail the course again. Thus, extra attention need to be taken by the students, parents and university and new method must be adopted in order to help them succeeded. In order to properly differentiate the reasons of the high failure rate, it is suggested that a diagnostic test should be done at the beginning of each semester. The personal advisors for each student should play a more active role purposely to monitor the performance of their mentees. The faculty should actively promote any workshop or peer tutoring activities to the students in order to motivate themselves in improving their performances. Nowadays, through online learning, the students can actively pursue knowledge at anytime and anywhere. Hence, it is suggested that if the lecturers do have extra notes or videos on solving Calculus problem, they can share their materials through any platform such as Open Learning to help the students to learn in their own pace.

Regarding the integration performance, only 33% of the repeaters rated as highly performed compared to about 75% of fresh students rated as high performed. Further analysis shows that 97.5% students rated as highly performed pass the final examination as compared to only 38.2% students with low integration performance pass the final examination. This represents the students with low integration performance have more tendency to fail the final examination and students with high integration performance have more chances to pass the final examination. This is consistent as stated by [4] that students' do have difficulties in coping with integration. Therefore, the integration part should be stressed more while learning and teaching

Calculus. As the technology progressed, the education system may start to employ different technologies such as mobile applications that discuss in detail about integration to help students. This would help the students tremendously to study on their own at their own pace without depending too much on the classroom learning or feeling left out whenever they could not cope their friends' pace. The result of this study is only limited to the integration performance based on the exam activity. Future work will include the integration performance based on coursework grades.

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Competing Interests

Authors have declared that no competing interests exist.

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