Mathematical Sciences and Informatics Journal
Vol. 2, No. 2, Nov. 2021, pp. 57-66
http://www.mijuitmjournal.com
DOI : 10.24191/mij.v2i2.15934

Exploring Pre-Calculus Final Assessment Marks between Gender with Principal Component Analysis

Najihan Awang @ Ali
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak Branch Tapah Campus, Perak, Malaysia
najihanali@uitm.edu.my

Nurul Husna Jamian
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak Branch Tapah Campus, Perak, Malaysia
nurul872@uitm.edu.my

Muhammad Aslam Mohd Safari
Department of Mathematics, Faculty of Science, Universiti Putra Malaysia, UPM, Serdang 43400, Selangor, Malaysia
aslam.safari@upm.edu.my

Article Info
Article history:

Received May 05, 2021
Revised Aug 23, 2021
Accepted Oct 02, 2021

Keywords:

Pre-Calculus
Final Assessment
Gender
Question
Performance

ABSTRACT

Pre-Calculus covers additional algebraic and trigonometric, where the students are encouraged to become proficient in those topics to prepare for an in-depth calculus learning. In Universiti Teknologi Mara (UiTM), practically every semester the issue of Pre-Calculus' high failure rate is commonly reported. One of the ways to measure the students' understanding of this subject is through the final assessment performance. Besides, gender significance is one of the most notable studies in mathematics performance. Therefore, this study aims to compare the performance of part 1 diploma students who registered Pre-Calculus in UiTM Tapah in in accordance to their gender. To analyze the results, this study performed Descriptive and Principal Component Analysis using R statistical software. It was found that the students faced problems in answering Question 2, but scored more marks for Question 5. This revealed that most of the students faced difficulties in handling sketches of parabolas and circles. It was also discovered that the female students outperformed the males in this course.

Corresponding Author:
Nurul Husna Jamian
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, Perak, Malaysia.
email: nurul872@uitm.edu.my

1. Introduction

Mathematics is a core subject in every level of education. It starts from primary school, secondary school, and university or college level [1]. It is also a compulsory subject for all primary and secondary school students. Meanwhile, at university level, the students will be exposed to special majors in mathematics known as Calculus [2]. Most of the students do not realize the connection between mathematics and their majors. They only assume it being a compulsory subject, with some of them arguing the relevance of learning it in their major, and how would it become practical and implementable after graduation. They complain that the curriculum is loaded with too many mathematics subjects, and they are unable to see the connection between the two disciplines [3]. For instance, mathematics has become a compulsory course in engineering courses in order to implement practical applications of mathematical equations, and in-depth understanding of real-world problem solving among the students [4].

However, it is very disappointing to mention that the undergraduate students' performance on some mathematics subjects is not encouraging anymore [5]. There is sufficient evidence showing

PENERBIT PRESS UNIVERSITI TEKNOLOGI MARA

that many students gave negative feedbacks as they failed in mathematics courses [3, 5]. Thus, they could not justify the relationship between mathematics subjects and their primary fields. So, it is crucial to investigate the weakness of the students, especially in answering the final assessment questions. It will encourage the lecturers or instructors to improve their delivery of teaching for specific topics in mathematics subjects. Additionally, getting insight on the students' background and pass performances in learning mathematics will help the lecturers to improve the teaching strategies. The significance of gender has been widely addressed raised in strategizing the learning and teaching mathematics [5].The female students outperformed male students in the examination of Sijil Pelajaran Malaysia (SPM) of Mathematics subject from 2000 to 2004. Therefore, the objective of this study is to identify the impact of gender on the students' learning performances who registered Pre-Calculus in UiTM Tapah.

2. Literature Review

Students who have a good background in mathematics and advance mathematics will better understand the university-stage mathematics. In the Malaysian school system, Additional Mathematics is a more advanced subject compared to Mathematics. Usually in most university, Additional Mathematics is the first subject to be registered by the engineering and computing students. So, the performance of the students during their secondary school years will influence their achievement in the university. The students must understand that university-level contents are continuously upgraded from secondary school, as they have entered the next stage.

According to studies, students have difficulties in learning mathematics when they have poor comprehension of the basic ideas, low computational skills, the inability to properly arrange existing information, and are unfamiliar with mathematical languages and symbols [6]. A research conducted by [6] found that the majority of the students did not sit for Additional Mathematics subject in their secondary school level. Even if they took the subject, many of them received a failing grade. When answering mathematics questions, this group of students commonly makes blunders or errors. According to researchers in [7] who said that students who obtained a low mathematics grade struggled in their Pre-Calculus mathematics courses. In contrast, the students who entered university with good results in Mathematics and Additional Mathematics will better understand and perform in Pre-Calculus [8]. It is vital to highlight the students' background in Mathematics and Additional Mathematics will affect their performance in the university. However, it is not exactly 100 percent correct if the students put a considerable amount of effort and attention to class. So, the lecturers need to identify their students' Mathematics and Additional Mathematics background in the first session of class. The lecturers are advised to pay more attention to a particular group of students who face difficulties in learning Mathematics.

In UiTM at diploma level, the students must attend Pre-Calculus coded as MAT133 as their preliminary subject for Calculus in semester one. Pre-Calculus covers additional algebraic and trigonometric topics where students are encouraged to become proficient both topics as a preparation for an in-depth learning of calculus. It consists of four significant sub-topics such as coordinates, graphs and lines, functions, systems of equations and inequalities, and trigonometry. In addition, the students must be skilled at solving exponential and logarithmic equations, linear and non-linear equations, and trigonometric equations. At the end of this course, the students are expected to be able to express the basic concepts of coordinates, graphs and lines, functions, systems of equations and inequalities, and trigonometry. Then, they are expected to be able to sketch graphs of essential and trigonometric functions. Finally, they are expected to be able to apply appropriate methods and procedures relating to trigonometric problems.

Currently, in open and distance learning (ODL), the continuous assessments are divided into four categories. One of the essential assessments is the final assessment. It contributes to 50 percent of the overall continuous assessment mark. Besides, its questions cover all the syllabus of MAT133. Almost every semester, some faculties would report a greater failure rate in Mathematics among their students. The passing and failing percentages in MAT133 of Diploma in Computer Science (CS110) students from UiTM Segamat, Johor was given in a study by [9]. From 2012 to 2014, the data of their final assessment scores were collected for at least six semesters. According to the statistics, 7.69 percent of CS110 students failed in semester 2 (2013/2014 session), rising to 40.6 percent in semester 3. [7] study revealed that the Heads of Programs of Mathematics courses voiced their concerns about their full-time diploma students' academic performance in UiTM Sarawak. From January-May 2004 semester, up through January-May 2007 semester, the data consisted of the results of final assessments. For the previous seven semesters, MAT133 was

identified as one of the highest failing-rate contributors in mathematics courses, with a failure rate of 31.34 percent. Therefore, one of the ways to measure the students' understanding of this subject is through their performance in the final assessment. This study aims to investigate the performance of the students in each question on the final assessment. University educators are responsible for exploring the potential and capability of their students in answering the final assessment of MAT133. The information obtained helps in identifying the topics that require more attention and exercises. Besides, this will encourage the resource persons (RPs) to evaluate the effectiveness and significance of the topics covered, and the teaching methods applied.

One of the most remarkable studies in student mathematics performance is the significance of gender. Gender differences, according to [10] are crucial to be researched because they have consequences, primarily in teaching and learning. Thus, it was emphasized that this will influence the teachers' perception of their students' performance. Researchers have previously produced inconclusive findings in this area, according to previous studies. According to certain studies, male students earn higher mathematics success levels than female students [11]. In [12], the researcher discovered no gender differences in the total of Mathematics achievement of their 1,078 high-school seniors in the 2002 Chinese College Entrance Examination as well as [10, 13].

In contrast to Malaysian statistics, researchers reported that female students outperformed male students in SPM Mathematics for five years (2000-2004) [14]. Meanwhile, [15] revealed a gendered performance disparity in the CAPE mathematics areas. In all of the data examined, girls consistently outperformed their male counterparts, except for Applied Mathematics Unit 2. Furthermore, evidence shows that female students in Diploma programs do better than male students in 'high-failure rate' Mathematics courses [7]. A study by researchers in [10] advises educators to examine the disparities in mathematics success between males and females when constructing their classroom teaching and learning strategies. This study investigates the trend of gender disparities in Pre-Calculus among students based on the varied output of researchers.

3. Methodology

This study involved 108 Part 1 diploma students who registered for MAT133 in September 2019 - January 2020 semester in UiTM Tapah. A dataset of final assessment results of MAT133 was used in this study, comprising of the students' particulars and marks of each question. Overall, the MAT133 final assessment consists of five questions, totalling 100 marks. The allocation of marks and topics covered for each question are shown in Table 1.

Table 1. Mark Allocations and Topics Covered Per Question

Question	Topic covered	Allocation Mark
Question 1 (Q1)	Inequalities, Absolute and Complex Number	18
Question 2 (Q2)	Coordinate Plane and Graph, Plane Analytic Geometry (Lines, Parabolas and Circles)	15
Question 3 (Q3)	Functions, Solution to Equations, Logarithmic and Transformation of Graphs	25
Question 4 (Q4)	Systems of Equations, System of Inequalities and Solutions to Trigonometric Equations	19
Question 5 (Q5)	Circular Measure, Graphs of Trigonometric Function, Six Trigonometric Ratio, Trigonometric Identities and Solution of Triangle	23

This study used R statistical software to perform the Descriptive and Principal Component Analysis (PCA). The Descriptive Analysis is presented in terms of minimum, maximum, and mean value to display the data and convey the information into a manageable way.

PCA was then performed in this study. It is a useful technique for exploratory data analysis to visualize the variations that are present in a dataset of many variables [16]. It was found that when the first two Principal Components (PCs) explained a significant portion of the variance in the data, it could be visualized by projecting the observations onto the span of the first two PCs. In a PCA, this plot is known as a Biplot. A Biplot overlays a score plot and a loading plot in a single graph. If the

data are well-approximated by the first two principal components, a Biplot enables the visualization of high-dimensional data using a two-dimensional graph [17].

A Biplot is constructed by using a singular value decomposition (SVD) to obtain a low-rank approximation to a transformed version of the data matrix Y, whose n rows are the samples (also called the cases, or objects), and whose k columns are the variables. Let Y be an $n \times k$ matrix holding the data. Y can be decomposed using a singular value decomposition (SVD) as in Equation (1)

$$Y = ULV' \tag{1}$$

where U is $n \times k$, and both L and V are $k \times k$. The elements of L, which are diagonal, are the so-called eigenvalues.

From the singular value decomposition, the coordinates of the observations are given by

$$G = UL^c \tag{2}$$

and the coordinates for the variables are given by

$$H' = L^{1-c} V' \tag{3}$$

In Equations (2) and (3), the scalar c can take any value between zero and one. Regardless of the value of c, the Equation (4) always holds.

$$GH' = UL^c L^{1-c} V' = ULV' = Y \tag{4}$$

However, as G is $n \times k$ and H is $k \times k$, all the coordinates have k dimensions. To plot these coordinates in a two-dimensional space, we must select two of them. Usually this is done by choosing those columns of G and H that correspond to the highest eigenvalues in L.

Choosing a value for c defines the coordinates for different types of Biplots. Three values for c are mostly used: $c = 1$ (row-metric preserving Biplot), $c = 0$ (column-metric preserving Biplot) and $c = 0.5$ (Symmetric Biplot). In this study, we used $c = 1$ to conduct the analysis using PCA Biplot.

4. Results and Discussions

4.1 Descriptive Statistics Results

The Descriptive Analysis results are shown in Table 2. It was found that the Minimum marks of Q1, Q2, Q3, Q4, and Q5 were 6, 2, 6, 7, and 3 respectively meanwhile the Maximum marks of Q1, Q2, Q3, Q4, and Q5 were 18, 15, 25, 19, and 23 respectively. The mean of marks for Q1, Q2, Q3, Q4, and Q5 were 12.85, 8.70, 18.72, 15.59, and 16.79 respectively.

Table 2. Descriptive Statistics Results

Question	Minimum	Maximum	Mean
Q1	6	18	12.85
Q2	2	15	8.70
Q3	6	25	18.72
Q4	7	19	15.59
Q5	3	23	16.79
Overall	32	98	72.66

According to Table 3, the students had difficulties in answering Q2 as it showed the greatest percentage (31%) in the level of weak performance followed by Q1 (14%), Q3 (7%), and both Q4 and Q5 at 4%. It is illustrated in Figure 3 where the PCA points are far from the vectors in Q2. It indicated that the students scored low marks for each sub-question in Q2. However, it differed from other questions illustrated in Figure 2, Figure 4, Figure 5 and Figure 6, where most of the PCA points are scattered nearer to each vector of sub-question. This revealed that the students feeble in sketching the graph of a parabola and a circle, covered under the topics of Coordinate Plane and

Graph, and Plane Analytic Geometry (Lines, Parabolas and Circles). However, Q5 had the greatest percentage (64%) in Good performance, followed by Q4 (57%), Q3 (56%), Q1 (34%) and Q2 (17%). It revealed that most students understood the topic of Circular Measure, Six Trigonometric Ratio, Trigonometric Identities and Solution of Triangle as they could write the correct answers.

Table 3. Students' Performance Level based on Final Assessment Questions

Question	Weak (%)	Moderate (%)	Good (%)
Q1	14	52	34
Q2	31	53	17
Q3	7	36	56
Q4	4	39	57
Q5	4	32	64

4.2 Principal Component Analysis (PCA) Results

The Skewness Statistic and Standard Deviation results that were obtained in this study are shown in Table 4. The data used in this study follows the normal distribution as the Skewness Statistics of each question falls within the range of -1 and 1. In addition, there are no significant outliers since the Standard Deviation showed more than 3.

Table 4. Skewness Statistic and Standard Deviation Results

Question	Skewness Statistic	Standard Deviation
Q1	-0.345	3.376
Q2	0.150	3.568
Q3	-0.699	5.100
Q4	-0.803	3.011
Q5	-0.865	4.483

Figure 1 displays the vectors of Q1 and Q2 being very close to each other. This indicates that marks of Q1 and Q2 have a strong association between them.

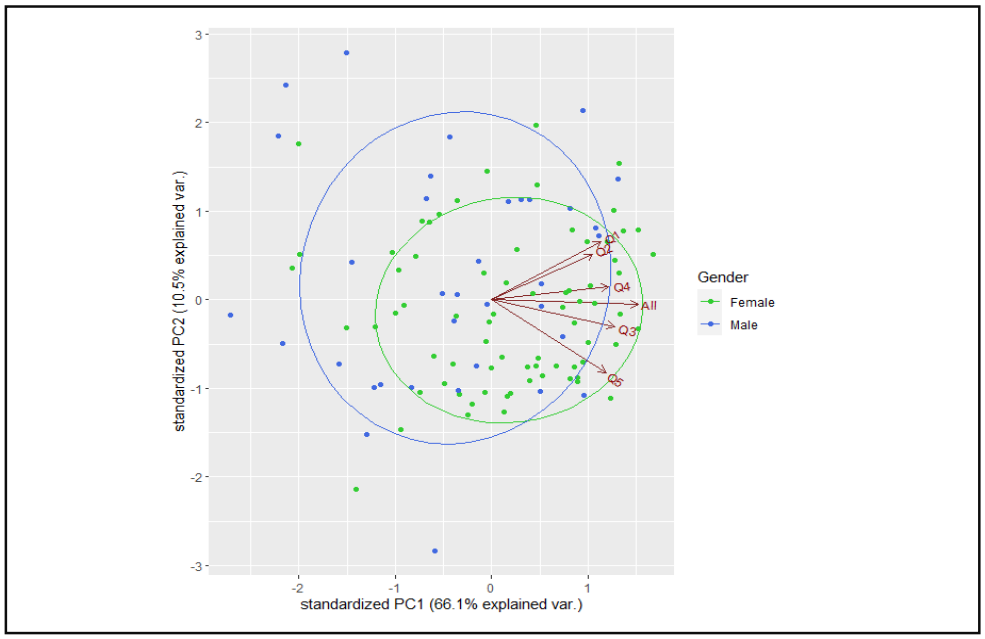

Figure 1. PCA Biplot of marks of different questions for male and female students.

Besides, as shown in Figure 1, the vectors of Q1 and Q5 have almost a 90-degree angle between them, which suggests that there is almost no association between the marks of Q1 and Q5. Then, the colored ellipses summarized the spread of PCA points of each group (gender). It observed that the female students had much smaller ellipse, and that their PCA points scattered much closer to the vectors than the male students. Thus, this study claims that the female students have better performance in answering the questions compared to the male students.

Figure 2 illustrates that the vector of bi is found to be the longest vector. It means that the variability of the students' marks for sub-question bi was higher than the other sub-questions. Then, it identifies that the vectors of a, bii and c are moderately close to each other where the marks of these sub-questions have a moderate correlation among them. Besides, the vectors of bi and c had almost a 90-degree angle between them, indicating zero association between the marks of sub-questions bi and c. Furthermore, it was found that the female students showed a smaller ellipse, and the PCA points scattered much closer to the vectors than the male students for each sub-question. Thus, the female students had a better performance in answering the sub-questions of Q1 than the male students.

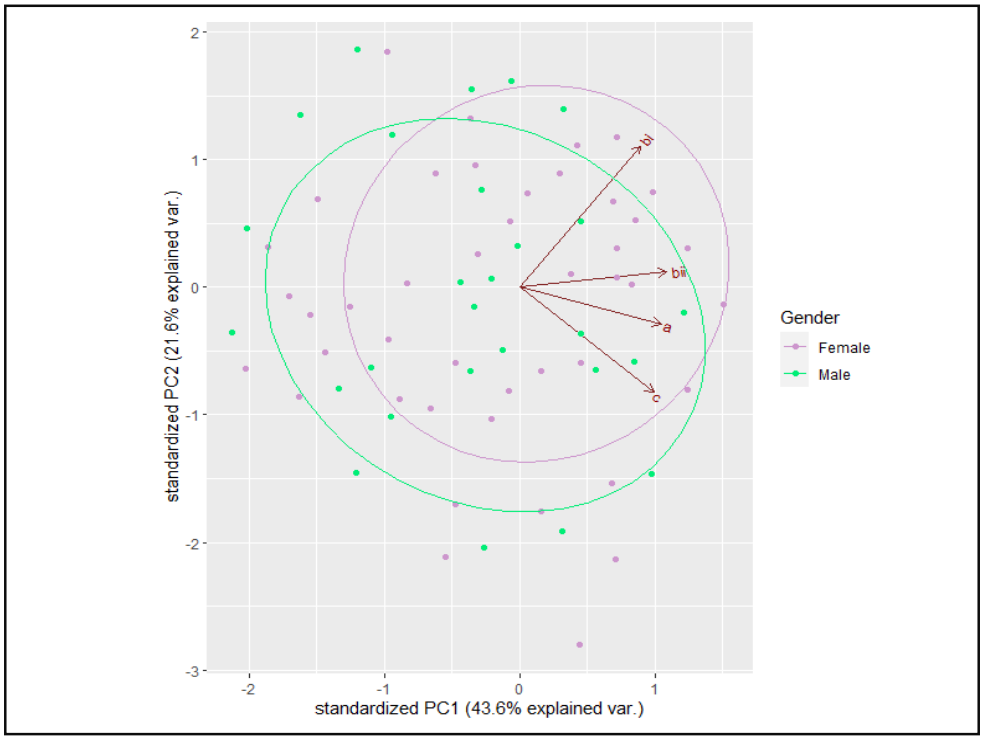

Figure 2. PCA Biplot for Q1

Figure 3 displayed that vector of c found to be the longest vector. It means that the variability of students' marks for sub-question c was higher than other sub-questions. Then, it identified that the vectors of a and b are moderately close to each other where the marks of these sub-questions considered having moderate correlation between them. Besides, the vectors of a and c had almost 90-degree angle between them indicating no association between these marks of sub-questions. In addition, it found that female students showed smaller ellipse and some of PCA points scattered closer to the vectors than the male students for each sub-question. Thus, female students had better performance in answering the sub-questions of Q2 rather than male students.

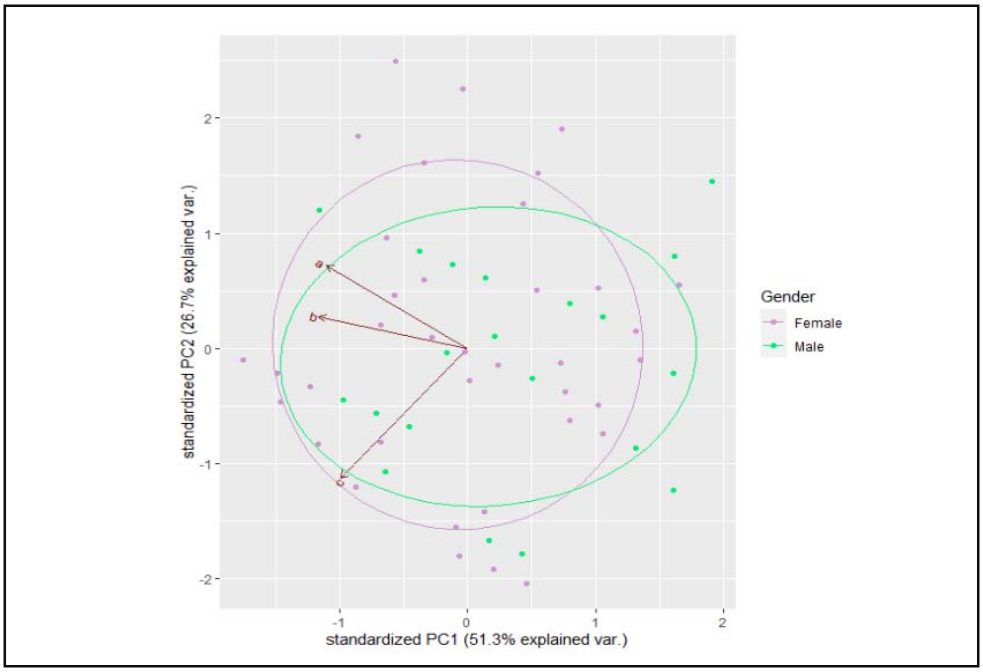

Figure 3. PCA Biplot for Q2

Referred to Figure 4, vectors of ai, aii, aii and d were found to be longer vectors as compared to the others. These suggested that the variability of the students' marks for sub-questions ai, aii, aiii and d were higher than sub-questions b and c.

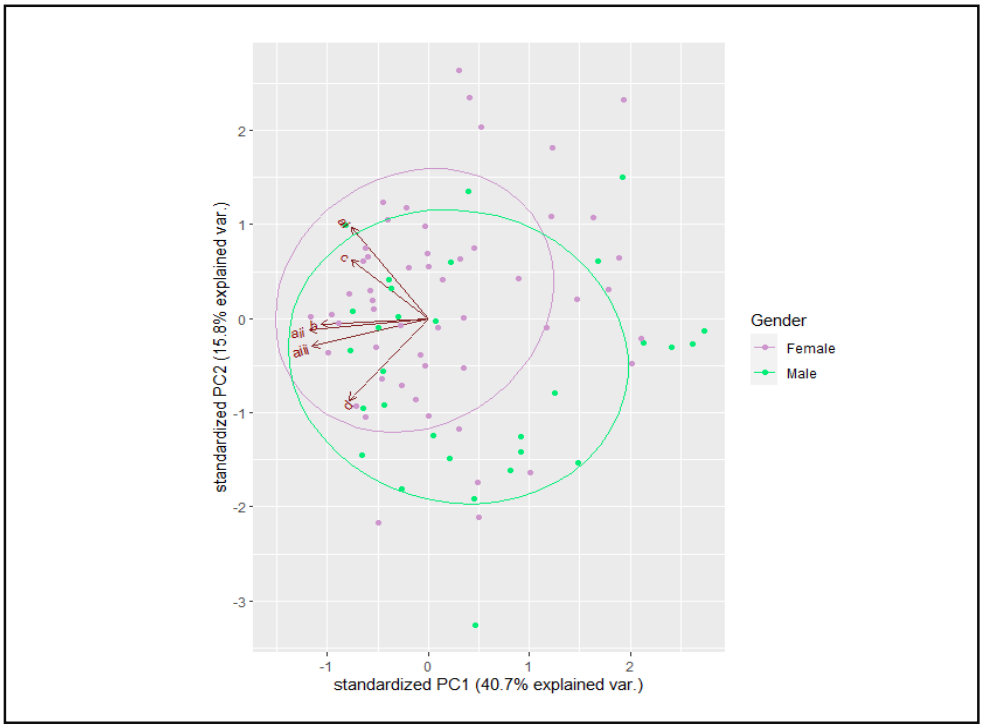

Figure 4. PCA Biplot for Q3

Then, it can be observed that the vectors of aii, aiii and b were very close to each other. Therefore, it is known that the marks of these sub-questions had a strong association among them. Meanwhile, there was a strong association between vectors of ai and c too. On the other hand, the vectors of ai and d had almost a 90-degree angle between them, which means that there was almost no association between the marks of sub-questions ai and d. This figure also showed that the female students had much smaller ellipses, and their PCA points scattered much closer to the vectors than the male students for each sub-question. This demonstrated that the female students had a better performance in answering the sub-questions of Q3, as compared to the male students.

Based on Figure 5, it was found that the vectors of ai, aii, and c were longer compared to vector b. It described that the variability of the students' marks for sub-questions ai, aii, and c were higher than sub-question b. Then, vectors ai and c were moderately close to each other. It can be explained that the marks of these sub-questions had a moderate association between them. Meanwhile, vectors ai and aii had almost no association between the marks of the sub-questions due to having an almost 90-degree angle between them. The ellipse belonging to the female students was obviously smaller than the male students, and their PCA points scattered closer to the vectors than the male students for each sub-question. This shows that the female students performed better in answering the sub-questions of Q4 compared to the male students.

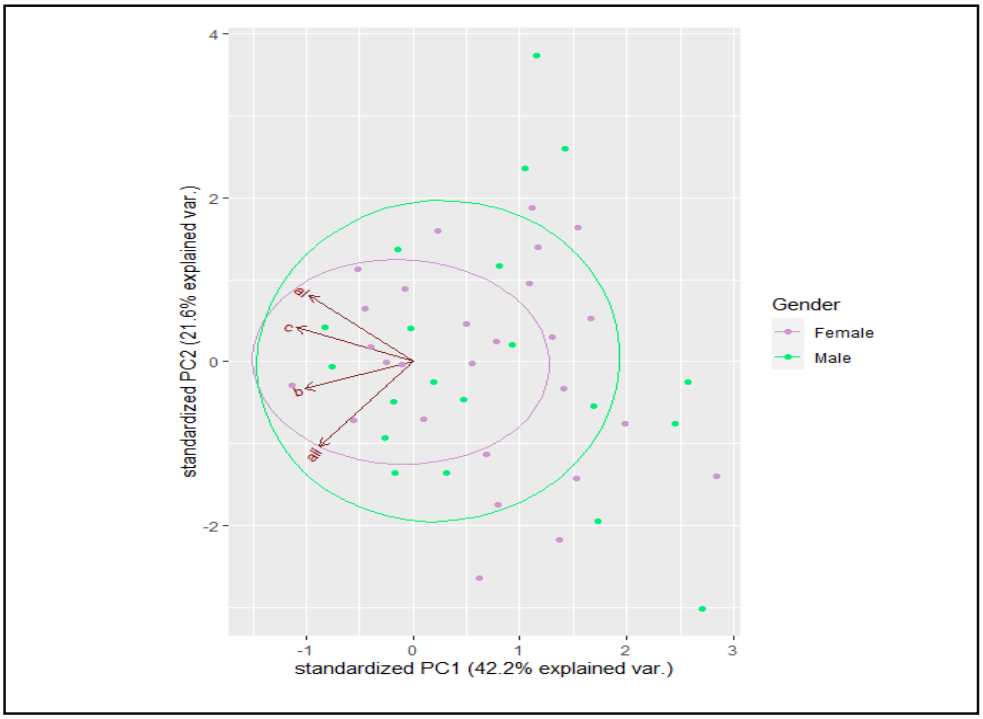

Figure 5. PCA Biplot for Q4

According to Figure 6, it was discovered that some vectors such as aii, aiii, ci, cii, and di were longer than vectors ai and b. The figure presents the variability of the students' marks for these sub-questions being higher than sub-questions ai and b. Then, the vectors of di and dii appeared very near to each other. The other vectors like ai, aii, and aiii were also found to be very near to each other. The same goes to vectors d and cii, as they were found being near to each other as well. These indicated that the nearer vectors among them had a strong association among marks of these sub-questions. Meanwhile, the vectors of cii and di were considered as having no association between the marks of the sub-questions because their angles were almost 90-degree. The ellipse belonging to the female students visibly appeared smaller than the male students, whilst their PCA points scattered much closer to the vectors than the male students for each sub-question. This shows that the female students had a better performance in answering the sub-questions of Q5 compared to the male students.

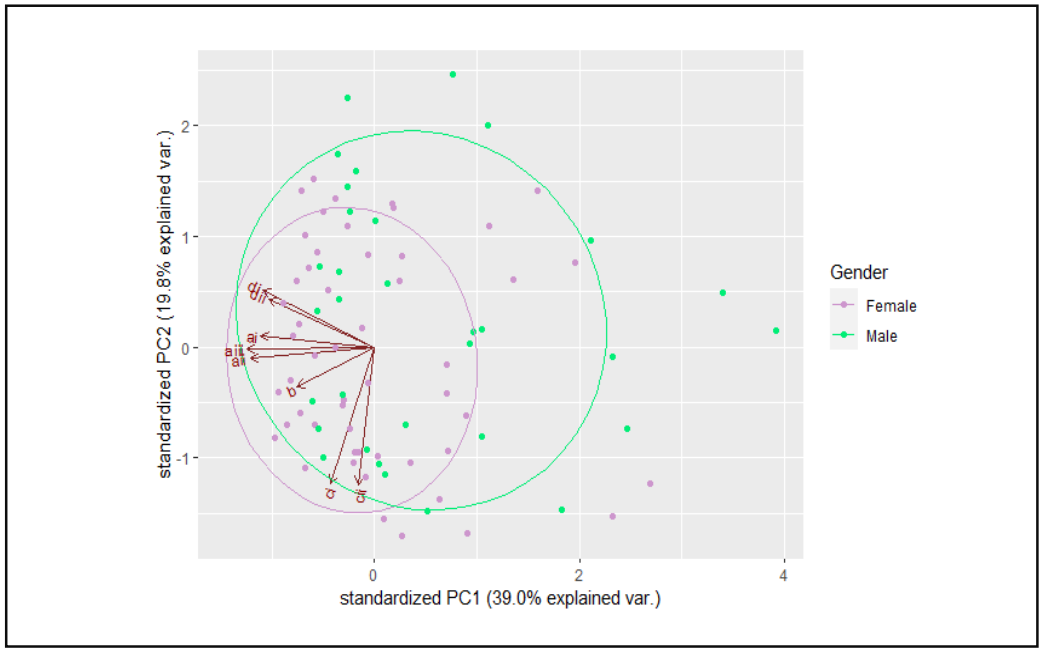

Figure 6. PCA Biplot for Q5

4. Conclusion

As a conclusion, most student had some difficulties in answering Question 2 that covered the topics of Coordinate Plane and Graph, and Plane Analytic Geometry (Lines, Parabolas and Circles). In contrast, the students scored more marks in Question 5, where most of them were able to understand the topics of Circular Measure, Six Trigonometric Ratio, Trigonometric Identities and Solution of Triangle as they managed to write the correct answers. Furthermore, this study has revealed that the female students outperformed the male students in their final assessment for Pre-Calculus. Thus, gender played a role that affected the performance of the students in their Pre-Calculus final assessment. The lower performance of male students in university mathematical problem solving requires much attention and further actions from the mathematics lecturers. They are suggested to identify the disparities in mathematics performance between gender when setting their teaching and learning strategies. In addition, instead of teaching using the conventional method, the lectures should approach their students with visualized tools like Wolframalpha software and Desmos website application.

Acknowledgements

The authors would like to thank Universiti Teknologi MARA, Perak Branch, Tapah Campus for the facilities and moral supports to complete this study.

References

[1] N. Nizaruddin, M. Muhtarom, and M. S. Zuhri. "Improving mechanical engineering students' achievement in calculus through problem-based learning." *Universal Journal of Educational Research*, vol. 7, no. 12, pp. 2729–2733, 2019.

[2] S. Fatimah, Yerizon, "Analysis of Difficulty Learning Calculus Subject for Mathematical Education Students", *International Journal of Scientific & Technology Research*, vol. 8, no. 3, 2019.

[3] J. L. E Agatep, "Student Performance in Pre-Calculus Courses: Unbolting Gate for Success in Differential Calculus", *Sch J Appl Sci Res*, vol. 1, pp. 47–50, 2018.

[4] P. Revathy, R. Prabakaran and S. Muthukumar, "Contemporary Issues in Teaching and Learning Techniques of Differential Equations: A Review among Engineering Students", *International Journal of Advanced Science and Technology*, vol. 29, no. 7, pp. 1313 – 1330, 2020.

[5] A. M. Nasir, N. A. B Omar, E. S. B. Sarudin, S. Masrom and N. H. Ahmad, “Teaching and learning of pre-calculus: An insights of educators”, *Journal of Fundamental and Applied Sciences*, vol. 9, no. 6S, pp. 452–467, 2017.

[6] S.F. Fuzi, W.H.W. Hassan, S.N. Zainudin, S.R. Jama, N.E. Zahidi and B. A. Halim, “Moderating Effects of Additional Mathematics’ Achievement During SPM on the Relationship Between Performance in Modern Mathematics and Mathematical Errors Occurrences: A Case Study of MDAB Students in UiTM Melaka”, *ASM Sc. J.*, vol. 13, 2020.

[7] H. E. Tang, L.L. Voon and N. H. Julaihi, “A Case Study of 'High-Failure Rate' Mathematics Courses and its’ Contributing Factors on UiTM Sarawak Diploma Students”, *Conference on Scientific & Social Resource*, vol. 8, no. 1, 2009.

[8] W.N.H. Wan Abdul Aziz, A. Abdul Rahman, J. M. Said amd S.S. Shaffie, “The relationships between high school mathematics and pre-calculus performance in university”, *Multidisciplinary Informatics Journal*, vol 2, no. 2, pp.126– 132, 2019.

[9] S.N. Ahmad, S. Mahadi, M.Y. Yusri, H. Yusop, M.N. Ali and C.H. Heng, “Factors Related to Students’ Performance in Calculus”, *Journal of Applied Environmental and Bilogical*, vol. 7, no. 6, pp. 51– 133056, 2017.

[10] H. Shamsuddin, N.A. Razak, L.M. Thien, and A.Z. Khairani, “Do Boys And Girls Interpret Mathematics Test Items Similarly? Insights from Rasch Model Analysis”, *Asia Pacific Journal of Educators and Education*, vol. 35, no.1, pp.17-36, 2020.

[11] M. Gurian, P. Henley and T. Trueman, *Boys and Girls Learn Differently*, United States of America: Wiley, 2001.

[12] M. Tsui, “Gender and Mathematics Achievement in China and the United States”, *Gender Issues*, vol. 24, pp. 1– 11, 2007.

[13] E. Ghasemi, H. Burley, and P. Safadel, “Gender differences in general achievement in mathematics: An international study”, *New Waves Educational Research & Development,* vol.22, no.1, pp. 27–54, 2019.

[14] H. Hamzah, S. R. Ariffin & R. M. Yassin, “Girls’ Overachievement in the National Examination: Can Type of Items be the Cause?” *Journal of Science and Mathematics Education in Southeast Asia*, vol. 29, no. 2, pp. 1–20, 2006.

[15] L. George, “Exploring the M in STEM: post-secondary participation, performance and attrition in mathematics”, *Canadian Journal of Science, Mathematics and Technology Education*, vol. 20, no. 3, pp. 441–461, 2020.

[16] Y. Aït-Sahalia and D. Xiu, “Principal component analysis of high-frequency data”, *Journal of the American Statistical Association*, vol. 114, no. 525, pp. 287–303, 2019.

[17] J. E. Jackson, *A User’s Guide to Principal Components*, New York: Wiley, 1991.