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Assessing Gender Disparity in Mathematics Performance Following Project-Based Learning (PBL): A Statistical Evaluation Using T-Test

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Abstract: *Gender disparity in academic performance has been extensively discussed and documented in the literature. Mathematics, historically viewed as a stereotypically male domain globally, has been a focal point for examining gender disparities in achievement, with the exception of Malaysia. Due to these mixed findings, it has been suggested that innovative teaching and learning approaches can help mitigate gender disparities in academic performance and retention. However, there is a lack of research assessing gender disparities in mathematics achievement using Project-Based Learning (PBL) in Malaysia, particularly within the context of learning mathematics in the built environment. This study aims to explore whether PBL, compared to traditional methods, impacts gender disparity in mathematics achievement. This study employed a quantitative research design to investigate the impact of PBL on gender disparity in mathematics achievement among students in the Architecture and Environmental Design program. End of semester examination marks of 106 students were analysed using an independent t-test to compare the performance of female and male students. The results showed no statistically significant difference in mathematics achievement between female (M=29.54, SD=6.74) and male (M=27.79, SD=6.81) students, with t(104) =1.319, p =0.190. This suggests that the application of PBL in mathematics for the built environment may help reduce gender disparity. The findings have pedagogical implications for improving learning quality and developing student competency. This aligns with Sustainable Development Goal 4 (SDG 4), which aims to reduce disparities and inequities in education, focusing on both access and quality.*

Keywords: Gender Disparity, Mathematics, Project-Based Learning, T-Test

1. Introduction

Gender disparity refers to the unequal treatment and opportunities experienced by individuals based on their gender, impacting various aspects (Barriga et al., 2023). In the context of education, gender disparity refers to the unequal access, opportunities, and outcomes experienced by students based on their gender. This disparity can manifest in various ways,

including differences in academic performance, enrolments in certain subjects, and access to educational resources (Ahuja & Garutsa, 2024).

In the past (Di Tommaso et al., 2024; Thien & Ong, 2015), males generally had higher enrolment and better academic performance in science, technology, engineering, and mathematics (STEM) subjects at the tertiary level compared to females (Wrigley-Asante et al., 2023). This male advantage in science and math often led to more employment opportunities for men in related professions. Mathematics, traditionally perceived as a male-dominated field, has been a key area for studying gender disparities in achievement (Di Tommaso et al., 2024; Vos et al., 2023; Thien & Ong, 2015).

Conversely, recent studies in both developed and developing countries have revealed a reversal in the global trend, with females now outperforming males academically across most disciplines, including STEM fields (Arroyo-Barrigüete et al., 2023; Kühhirt et al., 2023). This is because, females are more likely to focus on long-term academic objectives, develop more efficient study habits, and demonstrate better self-regulation, all of which help them perform consistently in all courses, particularly STEM, which calls for constant work and close attention to detail (Tsaousis & Alghamdi, 2022). Females seem to excel not just in language arts, but also in the natural sciences, despite these being traditional areas of male dominance (Saadat et al., 2022). The gender performance gap switches in favor of females by the time they reach the tertiary level, even in countries where females face challenges accessing education and are underrepresented in STEM programs at the undergraduate and postgraduate levels (Wrigley-Asante et al., 2023; Saadat et al., 2022). In addition, females are more likely to focus on long-term academic objectives, develop more efficient study habits, and demonstrate better self-regulation, all of which help them perform consistently in all courses, particularly STEM, which calls for constant work and close attention to detail (Tsaousis & Alghamdi, 2022).

In Malaysia, however, the trend has been different where females outperformed males in education achievement including in mathematics education (Elhadary & Samat, 2023; A Rashid et al., 2021; Ahmad et al., 2017). Additionally, in recent years, female students have consistently outnumbered and outperformed males in mathematics assessments, including international tests such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) (Elhadary & Samat, 2023). Nonetheless, a noteworthy exception occurred in 2011, when males outpaced females in mathematics education. This anomaly was linked to the use of higher-order thinking skills (HOTS) teaching techniques and potential gender bias in tests (Ahmad et al., 2017).

While progress has been made in promoting gender equality in education, significant disparities still exist, especially in access to higher education and certain disciplines like STEM (Saadat et al., 2022). Factors contributing to these gender differences include individual perceptions about STEM subjects, stereotypes surrounding them, teaching methods influenced by gendered ideologies, and cultural norms prioritizing male education over females (Arroyo-Barrigüete et al., 2023; Wrigley-Asante et al., 2023; Saadat et al., 2022). An often-overlooked factor in the mathematics gender gap is the method of teaching mathematics. It has been suggested that innovative teaching and learning approaches can help mitigate gender disparities in academic performance and retention (Torrico et al., 2023; Eze et al., 2021). There are three common types of innovative teaching and learning approaches which are project-based learning (PBL), problem-based learning, as well as research-based learning and currently in trend is gamification (Sailer & Homner, 2020; Smiderle et al., 2020).

To highlight, PBL is one of these strategies that stands out as being very successful in reversing these discrepancies (Harisanti et al., 2024; Hadi et al., 2024; Eze et al., 2021) including in mathematics education (Di Tommaso et al., 2024; Johnsen et al., 2024; Rijken & Fraser, 2023). Research suggests that this approach, where students participate in discussions and investigative learning activities within a low competition setting, can reduce or even eliminate the gender gap in math performance (Di Tommaso et al., 2024). PBL places a strong emphasis on group projects that require students to interact with the content in-depth and cooperate to find solutions to actual issues (Harisanti et al., 2024; Hadi et al., 2024; Eze et al., 2021). PBL's introduction into mathematics education has generated a lot of discussion and controversy. Mathematics knowledge is required in the context of the built environment, which is defined as the human-made surroundings (i.e., buildings, parks, and infrastructure) (Mumu et al., 2021). This is due to the fact that establishing an artificial environment requires several calculations. In addition, (Mumu et al., 2021) emphasized that students need to have a solid grasp of mathematical concepts and astute environmental knowledge to answer any problems relating to environmental mathematics.

However, there is a lack of research assessing gender disparity in mathematics achievement using PBL in Malaysia, particularly within the context of learning mathematics in the built environment. Based on a systematic literature review conducted between 2020 and 2024, there are 11,854 studies on PBL implementation in education, with 783 specifically focused on PBL implementation in mathematics education. Of these, 250 studies examine PBL implementation in mathematics education in relation to gender disparity, and only 19 studies specifically address this issue within the Malaysian context.

Therefore, this study aims to explore whether PBL, compared to traditional methods, impacts gender disparity in mathematics achievement especially in the context of learning mathematics in the built environment. Thus, two objectives have been set out purposely to achieve the aim which are (i) to assess the distribution and central tendencies of end-of-semester examination scores by genders, and (ii) to measure the significant difference in end-of-semester examination scores by gender. This study hopes to solve the issues on gender disparity in mathematics performance by identifying whether PBL provides a more equitable learning environment compared to traditional methods. By analyzing end-of-semester examination scores through the lens of gender, the research help to determine if PBL can effectively address and reduce the existing gender gaps in mathematics achievement, particularly within the context of learning mathematics in the built environment. This aligns with Sustainable Development Goal 4 (SDG 4), which goals to reduce disparities and inequities in education, focusing on both access and quality.

2. Methodology

This section discusses on how this research is being carried out. To achieve the study's objectives, a quantitative approach was adopted, which provided a comprehensive evaluation of the project-based learning (PBL) impact on gender disparity. This approach allowed for a detailed analysis of statistical data, ensuring a thorough assessment of the outcomes.

The research population comprises 250 students from the Architecture and Environmental Design (AED) program, with a sample of 106 students selected using stratified sampling with proportional allocation. The sample includes 53 male students and 53 female students, ensuring equal representation of both genders.

This research employs a primary data collection method, utilizing existing end-of-semester examination scores as the source of data to analyse gender disparities in mathematics academic performance. By examining these examination scores, this research may help to uncover any potential differences in mathematics performance between male and female students in AED program, following PBL implementation.

For data analysis, the study will use two primary techniques to address its objectives. First, measures of central tendency (e.g., mean, median, and mode) will be employed to analyse the distribution and central tendencies of end-of-semester examination scores by gender, which corresponds to objective one. This will help summarize and compare the overall performance of male and female students in the subject. Second, an independent t-test will be utilized to assess the significance of differences in end-of-semester examination scores between genders, aligning with objective two. This test is appropriate for analysing performance data in a standardized academic setting because it assumes a normal distribution of scores and equal variance across groups, particularly made to compare the means of two independent groups (e.g., male and female students) and determine if observed differences are statistically significant.

To highlight, the independent samples t-test relies on five key assumptions: independence of observations, normality, equal variances, scale of measurement, and random sampling to ensure the validity of the results. Firstly, it is crucial to assume of observational independence; that is, the data points in one group should not affect the data points in the other group (Hogg et al., 2013). Second, each group's data ought to be normally distributed (Hogg et al., 2013). The Central Limit Theorem, which asserts that the sample mean distribution approaches normality as sample size increases, makes this assumption less crucial for higher sample sizes (Hogg et al., 2013). Additionally, according to (Lumley et al., 2002) the t-test is relatively robust to non-normality, particularly for large sample sizes ($n > 30$).

The homogeneity of variances, which necessitates that the variances of the two groups under comparison be comparable, is another fundamental assumption. Levene's Test for equality of variances is used to evaluate this. The assumption of equal variances is said to be satisfied if the p-value from Levene's test is higher than 0.05 (Hogg et al., 2013). Furthermore, the data should be continuous. This means that the data should be measured on an interval or ratio scale (Hogg et al., 2013). Lastly, the data should be collected using a random sampling method to ensure the sample is representative of the population (Hogg et al., 2013).

This research tested the following hypotheses at 0.05 significant level.

H_0: There is no significant difference in the mean end-of-semester examination scores between male and female students.

H_1: There is significant difference in the mean end-of-semester examination scores between male and female students

3. Results and Discussions

This section presents the research findings on gender disparity impacts on mathematics achievement following project-based learning implementation. This research employing SPSS for both, descriptive and inferential statistics to address the first and second objectives. For the second objective, independent t-test is conducted to provide deeper insights.

The distribution and central tendencies of end-of-semester examination scores by genders: The data distribution and measure of central tendencies of end-of-semester examination are presented using a box plot as per Figure 1and 2.

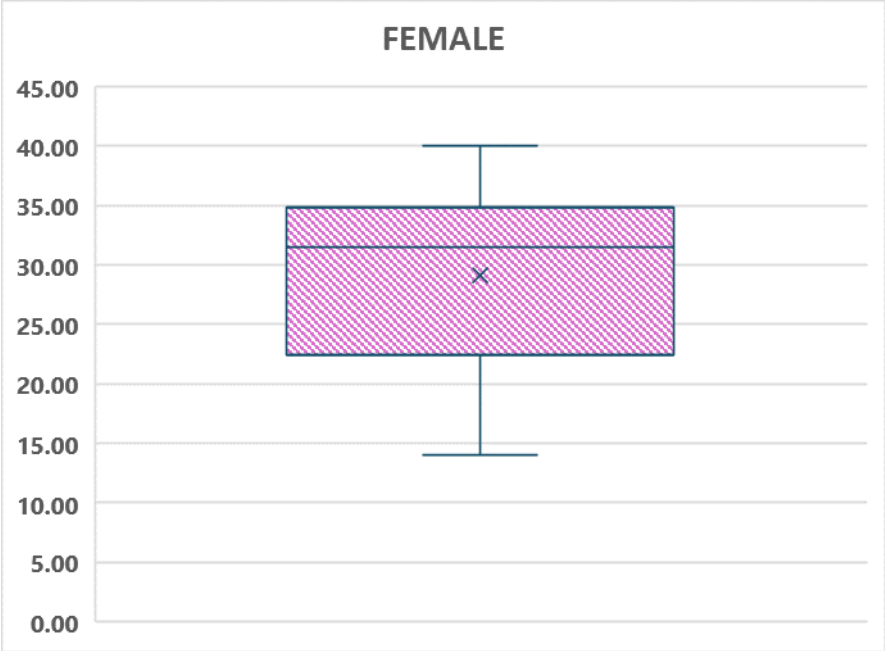

Figure 1: Box Plot of End-Of-Semester Examination Scores by Female Students

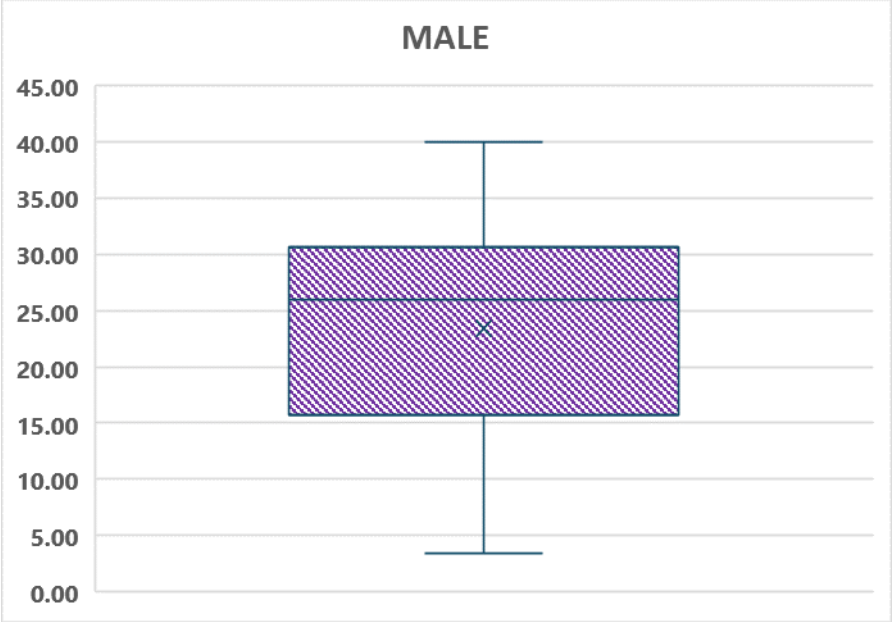

Figure 2: Box Plot of End-Of-Semester Examination Scores by Male Students

Figures 1 and 2 present a box plot illustrating the distribution of examination scores (out of 40) for male and female students. The data shows a slightly left-skewed distribution, indicating that the majority of students' scores are clustered towards the higher end of the scale. This skewness suggests a generally positive performance trend among students, with a concentration of higher scores.

Based on the calculated mean value, the average examination score for female students is 26.07, while for male students it is 23.44. This indicates that, on average, female students

performed better than their male counterparts. While the median score for female students is 29.50, compared to 26.00 for male students. The median values further support the observation that female students tend to achieve higher scores. The most frequently occurring scores are 30 for female students and 28 for male students. These mode values reinforce the trend observed in the mean and median, showing that the highest frequency of scores also favours female students. The result was found to be in accordance with the study performed by (Elhadary & Samat, 2023; A Rashid et al., 2021; Ahmad et al., 2017).

Statistical comparison of end-of-semester examination scores by gender: The measurement of significant differences in end-of-semester examination scores using t-test are presented in Table 1 and 2.

Table 1: Levene's Test for Equality Of Variances

	F	Sig.
Marks	0.287	0.593

Based Table 1, F (0.287) and Sig. (0.593) indicate that the assumption of equal variances is not violated. Thus, the row for 'equal variances assumed' for the t-test interpretation is used.

Table 2: T-Test for Equality Of Means

	t	df	Sig. (One-sided *p*)	Sig. (Two-sided *p*)	Mean Differences	Std.Error Differences	95% Confidence Interval of the Difference
Equal variances assumed	1.319	104	0.095	0.190	2.63019	1.99440	-1.32477 to 6.58515

Based Table 2, the independent t-test yielded a *t*-value of 1.319 with 104 degrees of freedom and a two-sided *p*-value of 0.190. Since this *p*-value is greater than 0.05, it indicates that there is no statistically significant difference in marks between the two groups. The mean difference between the groups is 2.63019, with a 95% confidence interval ranging from -1.32477 to 6.58515. This interval includes 0, further suggesting that the difference between the group means is not statistically significant. Therefore, the null hypothesis (H_0) is accepted.

Results presented in Tables 1 and 2 confirm the assumptions of equal variances. Additionally, the analysis meets the remaining four assumptions of the t-test. The observations, which represent gender, are independent of one another, ensuring that the samples are not related or paired. The data, consisting of end-of-semester examination scores, are on a ratio scale. Furthermore, the data were collected based on random sampling using stratified sampling technique, as highlighted in the methodology section. The assumption of normality is also met, given that the sample size is large, consisting of 106 students. This comprehensive adherence to the assumptions enhances the reliability of the test results.

4. Conclusion

In conclusion, this research examining the impact of Project-Based Learning (PBL) on gender disparity in mathematics performance reveals no statistically significant difference between the marks of the two groups analysed. The independent t-test results, with a mean difference of 2.63019 and a 95% confidence interval from -1.32477 to 6.58515, indicate that any observed differences in marks are not statistically significant. This finding is supported by the

confirmation that all assumptions of the t-test: normality, equal variances, independence of observations, ratio scale data, and random sampling were adequately met.

This suggests that the application of PBL in mathematics for the built environment may help reduce gender disparity. The findings have pedagogical implications for improving learning quality and developing student competency and learning quality.

Further research might investigate additional factors to gain deeper insights into the effectiveness of PBL in addressing educational inequalities.

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