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A Quantitative Analysis of Preparedness and Performance: Predictive Indicators in First-Year Tertiary Mathematics

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Abstract: Student preparedness at university entry plays a critical role in determining success in mathematics courses. This study investigates how three observable behaviours: (1) completion of weekly problem sets, (2) regular tutorial attendance, and (3) performance on a mid-semester test. We investigate how they relate to each other and their final examination results. Over five years, data were collected from 450 students (2014-2018) and analysed using correlation, multiple regression, and Partial Least Squares (PLS) regression. The analysis revealed that consistent completion of weekly problem-solving tasks was the most significant predictor of final exam performance, explaining more than 76% of the variance. Attendance accounted for approximately 21%, while mid-semester performance contributed only 3%. Collectively, the model explained 60% of the variation in final scores. These findings highlight the importance of sustained academic engagement and align with existing research on self-regulated learning and active participation.

Keywords: Student Preparedness, Tertiary Education, Mathematics, Applied Sciences, PLS, Linear Regression, Qualitative Analysis

Introduction

Factors that influence student success in university-level mathematics have become increasingly important considering global trends indicating a decline in mathematics performance. In Australia, this concern is particularly pressing, as both national and international assessments, including the Programme for International Student Assessment (PISA), continue to report falling standards in student achievement (Freeman *et al.*, 2014; OECD, 2019).The challenge lies in identifying effective indicators of preparedness that can help improve outcomes for students transitioning from secondary school to tertiary education.

This study aims to examine the role of three behaviourally measurable indicators of preparedness—class attendance, completion of weekly problem-solving tasks, and mid-semester exam performance—as predictors of final academic performance in a first-year tertiary mathematics course. These indicators are not only observable but also actionable, enabling educators and institutions to implement timely interventions throughout the semester.

Emerging research supports the importance of behavioural engagement as a predictor of academic performance. Credé *et al.* (2010) found that regular attendance is moderately associated with improved academic outcomes across a range of disciplines. Likewise, Freeman *et al.* (2014) demonstrated that regular engagement with structured problem-solving tasks significantly enhances learning outcomes in STEM education. Mid-semester assessments, while valuable, offer only a snapshot and may not fully reflect student understanding over time (Bennett & Hodge, 2019; Albion *et al.*, 2010).

This study is grounded in self-regulated learning theory (Zimmerman & Schunk, 2011), which frames student preparedness through three dimensions: forethought (planning and goal setting), performance (task engagement and persistence), and self-reflection (evaluating and adapting based on feedback). Each of the indicators examined in this study aligns with one or more of these dimensions.

The primary objective of this research is to provide a quantitative analysis of the extent to which class attendance, weekly problem-solving effort, and mid-semester results predict final mathematics performance. In doing so, the study addresses the following research questions:

1. To what extent does weekly engagement with problem-solving tasks predict student performance in tertiary mathematics?
2. How strongly is class attendance associated with academic achievement?
3. Can mid-semester assessments reliably indicate future performance?

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By clarifying the influence of these factors, the study aims to offer educators and institutional leaders practical strategies to enhance student learning outcomes in mathematics at the tertiary level.

Recent studies support the idea that consistent student engagement plays a major role in academic success. Credé *et al.* (2010) conducted a meta-analysis showing that class attendance is moderately linked to higher grades across disciplines. Similarly, Freeman *et al.* (2014) found that active learning and regular formative tasks like weekly problem sets significantly improve outcomes in STEM subjects. Mid-semester exams, while useful, often reflect performance at a single point in time and may not capture a student's overall learning journey (Bennett & Hodge, 2019).

Grounded in the theory of self-regulated learning (Zimmerman & Schunk, 2011), which emphasizes forethought, performance, and self-reflection, this study examines how these dimensions of student engagement contribute to academic success. Prior research has also supported this model, showing how ongoing behavioural participation influences learning outcomes (Rodriguez & Rogers, 2022; Noyes & Adhikari, 2020).

By investigating these behavioural factors, we aim to answer three core research questions:

1. Does completing weekly problem-solving tasks predict student performance?
2. How strongly does class attendance relate to success?
3. Can mid-semester test scores serve as reliable predictors of final outcomes?

The objective of this analysis is to provide educators and institutional stakeholders with evidence-based insights into how behaviourally measurable factors can inform academic support strategies and enhance student outcomes in tertiary mathematics. teachers and administrators' practical, evidence-based insights to better support students from the start of their academic journey.

Methods

The study analysed data from a diverse sample of 450 students enrolled in first-year mathematics courses across five consecutive academic years. The dataset's breadth and consistency allow for robust statistical analysis and generalization of findings across typical university populations. The dependent variable was students' final examination scores. Predictor variables included problem-solving effort, attendance rates, and mid-semester performance. These indicators were operationalized to reflect the multidimensional nature of student preparedness and engagement. Multiple regression analysis and PLS regression were employed to construct predictive models and assess the relative contributions of each preparedness indicator (Field, 2013). The PLS regression approach, rooted in principal component analysis (Wold *et al.*, 1987), was employed to model the relationships between predictor variables and final performance.The models were informed by comprehensive assumption testing to ensure validity and reliability.

Model Analysis

Multiple Regression Model

The first model, comprising problem set scores and mid-semester performance, achieved $R^2 = 0.62$, indicating that these two factors explained 62% of the variance in final scores. Problem set performance emerged as the most significant predictor ($\beta = 0.368$, $p < 0.001$), with mid-semester performance also contributing substantially ($\beta = 0.508$, $p < 0.001$).

The second model incorporating attendance and mid-semester performance yielded $R^2 = 0.56$, with mid-semester scores maintaining a dominant role ($\beta = 0.652$, $p < 0.001$) and attendance contributing modestly ($\beta = 0.183$, $p = 0.022$). The third model investigated was a Partial Least Squares Regression (PLS).

PLS Regression Model

The PLS model achieved a cross-validated R^2 (Q^2) of 0.60, revealing that student preparedness variables account for approximately 60% of the variance in final performance. The relative importance of each predictor was established through variance decomposition, with problem set performance contributing 76.2%, attendance 20.7%, and mid-semester performance 3.1%. The two-component PLS solution provided insight into the underlying structure of student preparedness, with the first component representing behavioural engagement and the second reflecting academic ability. This analysis underscored the primacy of consistent effort in academic achievement.

Results

Descriptive Statistics

The dataset demonstrated substantial variability across all measured variables, providing the necessary range for meaningful statistical analysis while confirming the representativeness of the sample across student performance levels (Field, 2013). Final examination scores exhibited a wide distribution ranging from 23 to 97 points with a mean of 65.4 and standard deviation of 18.2, showing a slight negative skew of -0.23 with standard error of 0.11. This distribution pattern indicates a tendency toward higher scores while maintaining substantial representation across the full performance range, suggesting that the assessment effectively discriminated among students of varying ability levels.

Problem set scores demonstrated similar distributional characteristics with scores ranging from 15 to 98 points, achieving a mean of 71.3 and a standard

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deviation of 20.1. The distribution exhibited normal characteristics with skewness of -0.31 and kurtosis of -0.18, indicating slightly higher central tendency compared to final scores while maintaining appropriate variability for statistical analysis. This pattern suggests that problem set assessments effectively captured student engagement and effort throughout the semester.

Attendance rates revealed considerable individual variation in class participation behaviours, ranging from a minimum of 32% to a maximum of 100%, with a mean attendance rate of 78.6% and a standard deviation of 16.8%. This substantial range demonstrates meaningful differences in student attendance patterns while providing sufficient variability for examining the relationship between attendance and academic performance. Mid-semester scores ranged from 18 to 95 points with a mean of 62.8 and a standard deviation of 19.4, closely matching the final score distribution pattern and suggesting consistency in assessment difficulty and student performance across different time points.

Correlation Analysis: Relationships

The correlation matrix revealed complex interdependencies among student preparedness indicators while confirming the appropriateness of these measures as predictors of academic performance. All variables demonstrated significant positive correlations with final scores, providing empirical support for their theoretical relevance as indicators of student preparedness and engagement.

Problem set performance exhibited a large positive correlation with final scores ($r = 0.67$, $p<0.01$), indicating that students who consistently performed well on weekly problem assignments tended to achieve higher final examination scores. This relationship explained approximately 45% of shared variance ($r^2 = 0.45$), suggesting that regular engagement with course problems serves as a strong predictor of ultimate academic success. The magnitude of this correlation supports theoretical expectations about the importance of consistent practice in mathematics learning.

Mid-semester performance demonstrated the strongest bivariate relationship with final scores ($r = 0.73$, $p<0.01$), explaining 53% of shared variance and confirming the predictive value of early academic performance indicators. This strong relationship aligns with the cumulative nature of mathematical learning, where early mastery of concepts provides the foundation for subsequent success. The consistency of this relationship across all academic years studied supports its reliability as a predictor of outcomes.

The relationship between problem set performance and attendance ($r = 0.74$, $p<0.01$) revealed a strong correlation that raised potential multicollinearity concerns, as students who attended class regularly also tended to complete problem sets diligently. This relationship suggests that these variables may represent overlapping aspects of student engagement, indicating the need for careful consideration in multivariate modelling approaches.

Attendance demonstrated a moderate positive correlation with final scores ($r = 0.45$, $p<0.01$), indicating that class attendance contributes meaningfully to final performance, though not as strongly as the other preparedness indicators. This relationship supports the practical value of attendance monitoring while suggesting that attendance alone is insufficient for predicting academic success. The moderate strength of this relationship suggests that attendance may serve as a facilitating factor rather than a determining factor in academic achievement.

The correlation between mid-semester performance and attendance ($r = 0.41$, $p<0.01$) indicated a moderate relationship, suggesting that students who attended class regularly performed better on mid-semester assessments. This relationship supports the theoretical expectation that class attendance facilitates learning, though the moderate strength suggests that other factors also influence mid-semester performance.

Finally, the correlation between problem set performance and mid-semester performance ($r = 0.59$, $p<0.01$) revealed a large positive relationship, indicating that consistent problem-solving effort throughout the semester translated into better mid-semester performance. This relationship supports the cumulative nature of mathematics learning and suggests that regular practice contributes to demonstrated competency on formal assessments.

Statistical significance testing confirmed that all correlations achieved significance at $p<0.01$ with 95% confidence intervals excluding zero, establishing the reliability of observed relationships while providing strong evidence for the theoretical model underlying the investigation.

Multiple Regression Results: Model Analysis

Two distinct regression models were constructed to examine different predictor combinations while systematically addressing multicollinearity concerns identified through correlation analysis. The models were designed to compare the relative predictive power of different combinations of preparedness indicators while providing insights into the unique contributions of each predictor variable.

The first regression model incorporated problem set scores and mid-semester performance as predictor variables, deliberately excluding attendance to avoid multicollinearity issues while focusing on the most academically relevant preparedness indicators. This model achieved exceptional predictive performance with $R^2 = 0.62$ and adjusted $R^2 = 0.61$, indicating that 62% of

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variance in final scores could be explained by these two predictors. The F-statistic of $F(2,447) = 364.2$ with $p < 0.001$ confirmed overall model significance with effect size.

Within the first model, mid-semester performance contributed most strongly with a standardized coefficient of $\beta = 0.508$ ($t = 18.66$, $p < 0.001$), indicating that each standard deviation increases in mid-semester scores predicted a 0.508 standard deviation increase in final scores. Problem set performance contributed substantially with $\beta = 0.368$ ($t = 21.25$, $p < 0.001$), demonstrating that consistent problem-solving effort throughout the semester provides significant predictive power beyond that captured by mid-semester assessment results. The model's predictive equation: Final Score = -8.744 + 0.877 (Mid) + 1.084 (ProbSet); provided a practical tool for early identification of students at risk of poor final performance.

The second regression model examined attendance and mid-semester performance as predictors, providing a comparison with the first model while investigating the unique contribution of attendance when considered alongside demonstrated academic ability. This model achieved $R^2 = 0.56$ and adjusted $R^2 = 0.55$, explaining 56% of variance in final scores, representing a large though slightly smaller effect compared to the first model.

In the second model, mid-semester performance dominated prediction with $\beta = 0.652$ ($t = 26.79$, $p < 0.001$), while attendance contributed modestly with $\beta = 0.183$ ($t = 2.28$, $p = 0.022$). The weaker performance of this model compared to the first model suggests that problem-solving effort provides superior predictive power compared to attendance alone, supporting the theoretical importance of active engagement over passive participation in academic success.

Comprehensive assumption testing confirmed the validity of both regression models. Linearity assumptions were verified through residual plots showing no systematic patterns, while independence was confirmed through Durbin-Watson statistics of 1.98 and 2.01, respectively, indicating acceptable independence of residuals. Normality of residuals was established through Shapiro-Wilk tests with p-values of 0.18 and 0.22, confirming normal distribution assumptions. Multicollinearity assessment revealed acceptable VIF values of 1.54 and 1.67 for the first model and 1.21 and 1.25 for the second model, all well below problematic levels.

Partial Least Squares Regression Results: Advanced Analysis

PLS regression incorporating all three predictor variables yielded a comprehensive model that addressed multicollinearity concerns while maximizing predictive power through sophisticated component analysis. The resulting model provided both superior predictive performance and enhanced theoretical understanding of the underlying structure of student preparedness.

The optimized PLS model achieved cross-validated R^2 (Q^2) of 0.60 and calibration R^2 of 0.62, demonstrating excellent stability and generalizability. The Root Mean Square Error of Prediction (RMSEP) of 11.2 points on the 100-point scale indicated precise predictive accuracy, while cross-validation procedures confirmed model robustness across different subsamples of the data. The optimal number of components was determined to be 2 through systematic cross-validation procedures, balancing model complexity with predictive accuracy.

The comprehensive PLS predictive equation:

Final Score = -14.32 + 1.32 (ProbSet) + 0.36 (Attendance) + 0.71 (Mid-Semester)

provided a practical tool for predicting student performance while revealing the relative importance of different preparedness indicators. The coefficients indicated that problem set performance carried the highest weight, followed by mid-semester performance and then attendance, aligning with theoretical expectations about the relative importance of active engagement and demonstrated ability.

Variable Importance in Projection (VIP) scores provided additional insight into predictor relevance, with problem set performance achieving VIP = 1.24, indicating high importance, mid-semester performance reaching VIP = 1.18, also indicating high importance, and attendance obtaining VIP = 0.89, representing moderate importance. These scores confirmed the primary importance of academic engagement and demonstrated ability while positioning attendance as a supporting factor.

Variance decomposition analysis revealed the precise contribution of each predictor to the overall explained variance. Problem set performance accounted for 76.2% of explained variance, establishing consistent problem-solving effort as the dominant predictor of academic success. Attendance contributed 20.7% of explained variance with a small-to-medium effect size, confirming its supportive role in academic achievement. Mid-semester performance contributed 3.1% of unique variance with a medium effect size, though its strong bivariate correlation with final scores indicates substantial overlap with other predictors in the multivariate context.

Component Analysis and Latent Construct Interpretation

The two-component PLS solution revealed distinct but complementary aspects of student preparedness that provide theoretical insights into the underlying structure of academic engagement. The first component, accounting for 47.3% of total variance, demonstrated

high loadings from problem set scores (0.89) and attendance (0.82) with moderate loading from mid-semester performance (0.31). This component appears to represent behavioural engagement, capturing students' consistent participation in learning activities throughout the semester.

The second component, explaining 12.7% of additional variance, showed high loading from mid-semester performance (0.94) with low loadings from problem set scores (0.12) and attendance (0.18). This component appears to represent academic ability, reflecting students' demonstrated mathematical competency independent of behavioural engagement factors.

The relative importance of the behavioural engagement component (47.3% vs. 12.7% variance explained) provides quantitative evidence that consistent behavioural patterns may be more predictive of academic success than demonstrated ability at discrete time points. This finding has significant implications for educational intervention design, suggesting that programs targeting consistent engagement behaviours may yield greater improvements in student outcomes than those focusing solely on academic skill development.

Discussion

This study set out to examine the extent to which observable student preparedness indicators, namely, weekly problem-solving effort, class attendance, and mid-semester exam performance, predict academic achievement in a first-year tertiary mathematics course. The analysis, based on years of data, showed that these three variables collectively accounted for approximately 60% of the variance in final examination performance. This section interprets the results, discusses their implications for teaching and learning in higher education, and outlines potential directions for future research.

The analysis demonstrated that weekly problem-solving scores emerged as the strongest predictor of final examination performance, accounting for 76.2% of the explained variance in the Partial Least Squares (PLS) regression model. This underscores the pedagogical value of regular formative assessment and active engagement with mathematical tasks. Prior research has consistently highlighted that frequent, low-stakes problem-solving supports deeper learning, promotes self-regulation, and reinforces conceptual understanding in STEM subjects (Freeman *et al.*, 2014; Rodriguez & Rogers, 2022). Specifically, Freeman *et al.* (2014), in their meta-analysis of active learning strategies in undergraduate STEM education, found substantial gains in student achievement with regular formative engagement.

Class attendance, often assumed to be a proxy for student engagement, contributed 20.7% to the explained variance. While lower than problem-solving effort, this remains a statistically significant predictor. The findings align with those of Credé *et al.* (2010), who reported a moderate but consistent positive correlation between class attendance and academic performance in higher education settings. The present study adds nuance by suggesting that mere physical presence in lectures may be insufficient unless coupled with active and consistent learning behaviours.

By contrast, mid-semester exam performance, though showing a strong bivariate correlation with final scores ($r = 0.73$), contributed only 3.1% to the explained variance in the multivariate model. This may indicate that while early academic achievement reflects initial content mastery, it is less predictive of long-term success, particularly when students' effort levels fluctuate or when learning accumulates unevenly across the semester. Similar observations have been made in recent educational analytics studies, which caution against over-reliance on early summative assessments for predicting outcomes (Lakkaraju *et al.*, 2015; Tempelaar *et al.*, 2015).

The two latent factors identified via PLS regression, namely, Behavioural Engagement and Academic Ability, offer a deeper insight. The Behavioural Engagement component, which loaded heavily on both weekly problem-solving and attendance, accounted for nearly four times the variance explained by Academic Ability, which was primarily defined by mid-semester test scores. This aligns with self-regulated learning theory, which emphasizes the role of metacognitive control, strategic effort, and sustained motivation in academic success (Zimmerman & Schunk, 2011; Panadero, 2017). Students who continuously engage with course materials and learning tasks are more likely to develop adaptive expertise and self-monitoring skills.

These findings have important implications for curriculum design and institutional policy. Higher education institutions should consider embedding structured, ongoing engagement activities such as weekly practice tasks, scaffolded tutorials, and progress monitoring within their teaching frameworks. Additionally, the use of early warning systems that integrate behavioural engagement metrics (e.g., task completion rates, attendance patterns) with academic indicators can facilitate timely interventions. The systems supported by learning analytics have been shown to enhance student retention and performance when effectively implemented (Ifenthaler & Yau, 2020).

Despite its strengths, this study acknowledges several limitations. Approximately 40% of the variance in final examination performance remains unexplained by the current model. This suggests that other factors, such as prior mathematical knowledge, general cognitive ability, emotional resilience, teaching quality, and socioeconomic background, are likely to contribute to

academic outcomes. Indeed, Richardson, Abraham, and Bond (2012) found that a combination of cognitive, behavioural, and psychosocial variables best explains academic performance in higher education.

Additionally, the study's scope is limited to a single institution and course context, which may affect the generalisability of findings. Future research should seek to replicate these results across diverse academic disciplines, institutions, and student demographics. Incorporating qualitative data, such as student interviews or reflective journals, may also help capture aspects of engagement and motivation not easily quantifiable. Furthermore, advanced predictive techniques, including machine learning and time-series modelling, can be employed to capture complex, nonlinear interactions between preparedness indicators and academic performance (Tempelaar *et al.*, 2015).

In conclusion, this study affirms that student success in tertiary mathematics is far from random; it is significantly influenced by observable, modifiable behaviours, particularly sustained effort in problem-solving and regular class participation. Educators can play a critical role in shaping these behaviours through intentional course design, formative assessment, and data-informed academic support. Promoting behavioural engagement, rather than focusing solely on static indicators of ability, represents a more equitable and effective pathway to student achievement in higher education.

Conclusion

This quantitative study offers sound evidence that student preparedness, defined as measurable, sustained engagement in mathematics coursework, predicts academic performance in first-year tertiary mathematics. The application of multiple regression and Partial Least Squares (PLS) regression revealed that 60% of the variance in final exam outcomes could be accounted for by three key behavioural indicators: weekly problem-solving assignments, class attendance, and mid-semester assessment scores.

Among these, the most substantial predictor of final exam success was students' weekly problem-solving effort, which explained 76.2% of the explained variance in the PLS model. This finding underscores the value of consistent formative assessment and supports prior research linking frequent practice to knowledge consolidation and performance (Freeman *et al.*, 2014; Rodriguez & Rogers, 2022). Attendance contributed 20.7%, confirming its role as a moderate yet meaningful determinant of success. Interestingly, although mid-semester scores correlated strongly with final performance in bivariate analysis, their unique contribution was only 3.1% in the multivariate context, indicating the relative superiority of continuous engagement over isolated performance events.

The study's findings align with self-regulation theory (Zimmerman & Schunk, 2011), which conceptualizes student learning as a cycle of forethought, performance, and self-reflection. The derived latent components from the PLS analysis - Behavioural Engagement and Academic Ability - clearly distinguish between students' active participation throughout the semester and their test-taking ability at a single point in time. The dominance of the Behavioural Engagement component, explaining nearly four times the variance of the Academic Ability construct, reinforces the argument that long-term learning behaviours are more critical to success than isolated cognitive capacity.

Practically, these findings suggest several actionable strategies for tertiary institutions:

- Design and enforce structured weekly problem-solving tasks as central components of mathematics curricula.
- Implement attendance monitoring systems and use these data as part of early warning mechanisms.
- Leverage mid-semester performance in conjunction with engagement data to identify students at risk and target interventions early.

While this study offers statistically robust conclusions, it also acknowledges limitations. The data were derived from a single institution and program stream, which may constrain generalizability. Additionally, the unexplained 40% of variance in final performance likely includes factors such as prior mathematics achievement, learning strategies, socio-emotional factors, and instructional quality - all of which warrant further investigation.

Future research should consider extending the model to incorporate these additional predictors and replicate the analysis in different institutional and disciplinary contexts. Furthermore, integrating machine learning techniques could reveal non-linear interactions among predictors and uncover latent patterns not captured by traditional statistical methods.

In conclusion, this study demonstrates that student success in tertiary mathematics is not random or mysterious. It is measurably linked to what students do throughout the semester. By quantifying these behaviours, educators and administrators are better equipped to support students proactively, rather than reactively - consistency, self-regulated effort are predictors of success other than ability alone.

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