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Mathematics in Transition: Assessing the Impact of Curriculum Changes on Student Performance Metrics

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ABSTRACT

Curriculum changes in higher education, especially in mathematics, are intended to align academic content with scientific advancements and evolving workforce demands; however, such reforms often bring unintended academic challenges for students. In Indonesia, recent changes in the 2016, 2020, and 2024 mathematics curricula introduced shifts in course credit allocations, course learning outcomes (CLOs), material scope, instructional methods, and evaluation systems. This study specifically aims to evaluate the impact of these curriculum changes on student academic performance across five core mathematics courses: Introduction to Data Science, Calculus 1, Calculus 2, Linear Algebra, and Mathematical Statistics. Employing a quantitative, exploratory approach, the research analyses academic records from 586 students using descriptive statistics and visualisation techniques such as boxplots and bar-line charts. The findings reveal fluctuating average grades and a general decline in pass rates, particularly under the 2024 curriculum, which introduced more complex CLOs, deeper content coverage, and application-oriented assessments. These results highlight the urgent need to balance curriculum innovation with student readiness and provide valuable insights for curriculum development and educational policy planning.

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A. INTRODUCTION

Curriculum changes in higher education are driven by rapid scientific advancements and the growing demands for global competencies (Shimizu & Vithal, 2022). In mathematics education, these changes aim to ensure that graduates possess not only theoretical mastery but also the applied skills needed in the digital and data-driven era. However, such reforms often lead to a paradox: while they strive to modernize education, they can also generate academic tensions. In the Indonesian context, curriculum changes may bring positive effects such as improved alignment with technological development but also unintended outcomes like reduced student achievement due to short adaptation periods (Setiyorini & Setiawan, 2023). Moreover, reforms frequently result in mismatches between design and implementation, which in turn undermine learning effectiveness (Bertram et al., 2021; Kalinowski et al., 2020; Ramasamy & Pasupathy, 2021). These dynamics raise a pressing question: Do curriculum changes in mathematics actually foster innovation, or do they unintentionally hinder academic performance?

The challenges of implementing curriculum revisions are intricately linked to the capacity of educators to adapt pedagogical practices. Studies show that systematic, mentorship-based professional development can enhance this capacity (Nalbantoğlu & Bümen, 2024; Kalinowski et al., 2020), although resistance often arises due to conflicting teaching philosophies, administrative burdens, and misalignment between instructors' approaches and the new curriculum goals (Kim, 2024; Roth McDuffie et al., 2018; So et al., 2024).

Furthermore, rigid designs that emphasize content overload and quantifiable accountability measures tend to neglect non-cognitive elements such as student foundational competence and teacher confidence (Alam & Mohanty, 2023; Bertram et al., 2021). The COVID-19 pandemic has further exposed systemic weaknesses in curriculum implementation, with studies reporting the emergence of hidden curricula, increased inequality, and reduced academic resilience (Mohebi Amin et al., 2024; Teixeira & Li, 2024). Psychosocial factors like motivation and self-regulation have been identified as critical mediators of success, particularly in mathematics learning during remote instruction (Nofriyandi & Andrian, 2022), although these factors interact complexly with student interest, self-efficacy, and engagement.

In light of these issues, new competency-based approaches such as those developed at the University of Campinas—call for a complete reconstruction of academic culture, emphasizing student readiness and pedagogical scaffolding (Franco et al., 2023; Annala et al., 2023; Buleque et al., 2020). Supportive peer environments and open learning spaces are also proven to strengthen students' confidence in their academic ability (Zysberg & Schwabsky, 2021), while an overemphasis on standardized metrics as seen in India's Outcome-Based Education (OBE) can marginalize important qualitative learning aspects (Ramasamy & Pasupathy, 2021). Attitudinal factors also play a role, with research in the UAE indicating that mathematics performance is more influenced by course level than gender, especially in terms of perceived instructor quality and resource adequacy (Moussa & Saali, 2022). Meanwhile, innovative strategies like embodied cognition Abrahamson et al. (2020) and mind mapping Altarawneh et al. (2023) offer potential but are often constrained by institutional limitations (Attard & Holmes, 2022; Campbel, 2020). Recent technological developments, particularly the use of AI-based platforms such as ChatGPT, have introduced new dimensions into the teaching and learning of mathematics. While these tools offer personalised assistance and iterative feedback (Govender, 2023), their application requires careful evaluation due to potential issues like overreliance and unequal access. In this context, aligning learning outcomes, teaching strategies, and assessment systems remains central to effective curriculum design (Remillard et al., 2019; Cai et al., 2024).

Given these complexities, this study aims to analyse the effects of the 2016, 2020, and 2024 mathematics curriculum revisions on students' academic performance in five foundational courses: *Introduction to Data Science*, *Calculus 1*, *Calculus 2*, *Linear Algebra*, and *Mathematical Statistics*. Using longitudinal data, this research explores how changes in course credit weights, learning outcomes, material scope, pedagogical methods, and evaluation systems relate to trends in students' average grades and pass rates—thus addressing the urgent need to evaluate curriculum effectiveness in supporting academic success.

B. METHODS

This study uses an exploratory quantitative approach to examine patterns in student academic performance related to curriculum changes across three periods: Curriculum 2016, 2020, and 2024. The focus is on five core mathematics courses: Introduction to Data Science, measuring academic performance. The analysis applies descriptive statistics, including mean, standard deviation, median, and interquartile range (IQR), to observe trends in student performance, such as changes in average grades, distribution patterns, and variation across curricula. This study does not perform statistical hypothesis testing, as the goal is to explore observable differences and performance fluctuations across curriculum designs.

To visualise the results, boxplots and bar-line charts were created to illustrate average scores, pass rates, and grade variability under each curriculum. These visualisations aim to enhance the interpretation of descriptive data and support an accessible understanding of academic trends across the curriculum reforms. All visualisations aim for clarity, accessibility, and objectivity (Donohoe & Costello, 2020). All data processing and visualisation were conducted using Microsoft Excel and Python (Pandas and Matplotlib libraries). These tools allow for transparent, replicable analysis and ensure accuracy in computing performance metrics across time.

C. RESULT AND DISCUSSION

The 2017–2024 curriculum changes involved adjustments in credit weight, scope of material, CLOs, teaching methods, and evaluation systems, aligning with developments in data science, AI, and big data. Analysis of official curriculum documents highlights key differences across these components.

1. Course Credit

Unlike the other four courses, Introduction to Data Science carries a weight of 2 credits in all curricula namely, the 2016, 2020, and 2024 and thus remains unchanged. On the other hand, Calculus 1 was changed from 2 credits in the 2016 Curriculum to 3 credits in the 2020 Curriculum and remains at three credits in the 2024 Curriculum. Calculus 2 was changed from 4 credits in the 2016 Curriculum to 3 credits in the 2020 Curriculum and remains at 3 credits in the 2024 Curriculum. Linear Algebra changed from 4 credits in the 2016 Curriculum to 5 credits in the 2020 Curriculum and remains 5 credits in the 2024 Curriculum. Mathematical Statistics was changed from 4 credits in the 2016 curriculum to 3 credits in the 2020 curriculum, and it remains at three credits in the 2024 curriculum.

2. Scope of Material

Table 1. Differences in the Scope of Material in the 2016, 2020, and 2024 Curricula

Course	2016 Curriculum	2020 Curriculum	2024 Curriculum
Introduction to Data Science	Focuses on probability, statistical distributions, and statistical inference	Similar to the 2016 Curriculum, with additional coverage of Data Science, Machine Learning, and probability in statistical modeling	Same as the 2020 Curriculum, but further expanded to include Big Data, AI, Machine Learning, and fundamental statistical analysis concepts
Calculus 1	Focuses on the real number system, limits, derivatives, integrals, and transcendental functions	This is identical to the 2016 Curriculum	It is similar to the 2016 Curriculum, with additional advanced integration techniques and exploring transcendental functions
Calculus 2	Focuses on transcendental functions, polar coordinates, multiple integrals, and sequences of real numbers	This is identical to the 2016 Curriculum	It is similar to the 2016 Curriculum, with expanded content on indeterminate limits, improper integrals, parametric coordinate systems, and infinite sequences
Linear Algebra	Covers systems of linear equations, Euclidean vector spaces, linear transformations, eigenvalues, and applications	This is identical to the 2016 Curriculum	This is identical to the 2016 Curriculum
Mathematical Statistics	Covers probability theory and distributions, multivariate distributions, special distributions, and distributions of functions of random variables	This is identical to the 2016 Curriculum	Similar to the 2016 Curriculum, with an additional focus on the distributions of two or more random variables

3. Course Learning Outcomes (CLOs)

The evolution of course learning outcomes (CLOs) across the 2016, 2020, and 2024 Curricula reflects a progressive shift from theoretical foundations to advanced, application-driven competencies. In the 2016 Curriculum, Introduction to Data Science emphasised mathematical theories and statistics, while Calculus 1 and Linear Algebra focused on foundational principles. By the 2020 Curriculum, these courses integrated practical applications—Data Science introduced basic data applications, Calculus 1 incorporated statistical calculus, and Linear Algebra restructured content with statistical applications. The 2024 Curriculum further modernised content: Data Science expanded to big data processing, Calculus 1 prioritised independent problem-solving for real-valued functions, Calculus 2 advanced to systematic solutions for multivariable functions, Linear Algebra introduced rigorous analysis of vector spaces and linear transformations, and Mathematical Statistics deepened into comprehensive probability and distribution frameworks. This trajectory underscores curricula increasingly prioritising analytical depth, real-world problem-solving, and alignment with technological advancements, albeit requiring careful calibration to balance complexity with student readiness.

4. Teaching Methods

The teaching methods in the 2016 Curriculum employed an inquiry-based learning approach, group discussions, presentations of discussion results, and problem-solving exercises. The 2020 Curriculum maintained these methods, emphasising discussions, presentations, and the assignment of group and individual tasks. The 2024 Curriculum introduced additional approaches, including flipped learning and interactive lectures. Similar methods were applied in Calculus 1 and Calculus 2, with the development of more interactive teaching methods in the 2024 Curriculum. In Linear Algebra, the changes from the 2016 to the 2024 Curriculum also reflect inquiry-based learning, complemented by discussions, presentations, group assignments, and flipped learning. Mathematical Statistics followed a similar pattern, expanding traditional approaches by incorporating flipped learning and interactive lectures in the 2024 Curriculum.

5. Evaluation Methods

The evaluation methods for Introduction to Data Science in the 2016, 2020, and 2024 curricula include essays, assignments, and presentations. In Calculus 1, the 2016 Curriculum added practicum sessions specifically for the Department of Mathematics, while the 2020 and 2024 curricula emphasised essays, assignments, and practicums without presentations. Calculus 2 in all three curricula employed evaluation methods consisting of essays, assignments, and presentations. In Linear Algebra, the 2016 Curriculum included practicum sessions for the Department of Mathematics, whereas the 2020 and 2024 curricula used essays, assignments, and presentations as evaluation methods. Mathematical Statistics consistently used essays, assignments, and presentations across all curricula. Subsequently, the curriculum changes will be analysed to determine whether they have significantly impacted students' academic performance. The following visualisation presents the distribution of the average grades and average graduation rates for five courses across three different curriculum periods, as shown in Figure 1 and Figure 2.

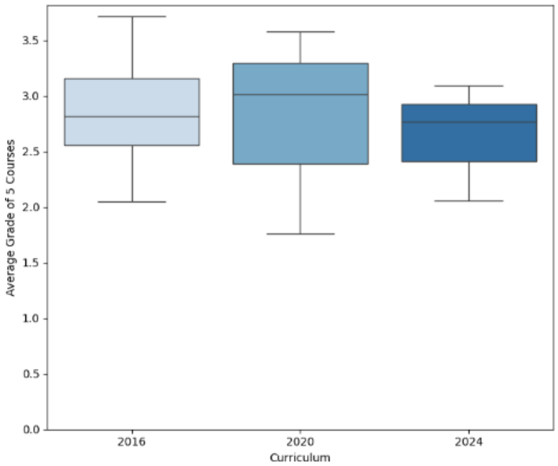

Figure 1. Distribution of Average Grades in 5 Courses

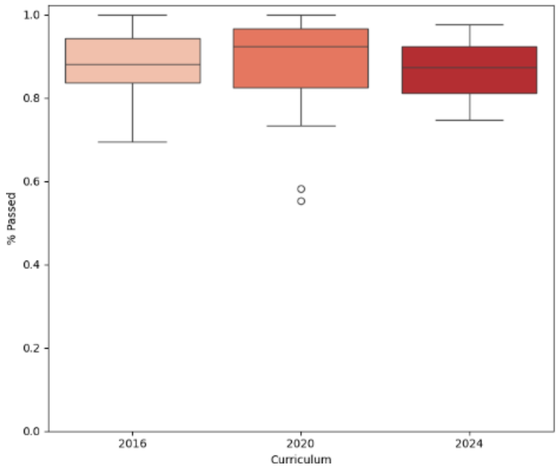

Figure 2. Distribution of Average % Passed in 5 Courses

The 2020 curriculum has the highest median grade (3015) and the broadest interquartile range (IQR: 0.905), reflecting significant academic Performance variation and stronger overall outcomes despite a symmetrical distribution without outliers. In contrast, the 2024 curriculum shows the narrowest IQR (0.515) and a lower median (2.770), suggesting more consistent but weaker results with a slight right skew. For graduation rates, the 2020 curriculum again leads (median: 92.30%, IQR: 0.1423) but includes outliers requiring further investigation, while 2024 exhibits more uniform yet lower rates (87.34%). Overall, the 2020 curriculum demonstrates higher and more varied achievements, whereas 2024 prioritises consistency at the expense of performance.

A standard deviation analysis was conducted to examine the impact of curriculum changes on the variability of student grades. As a statistical measure of dispersion, standard deviation reflects the degree to which grades deviate from the average. Higher values indicate greater disparity in student performance, while lower values suggest more uniform outcomes. Comparing standard deviations across curricula helps determine whether curriculum revisions promote consistency or increase performance gaps. As emphasised by (Febriani, 2022), standard deviation is essential for assessing the consistency of learning outcomes and understanding the effects of educational interventions.

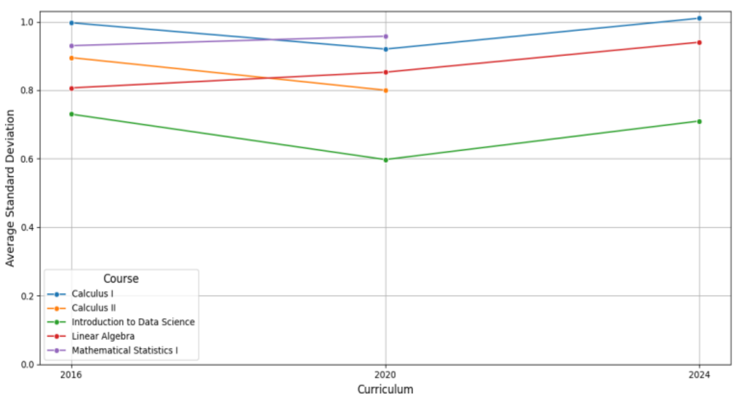

Figure 3. Average Standard Deviation of Grades per Curriculum for 5 Courses

The chart reveals differing patterns of grade variation across courses in response to curriculum changes. Calculus 1 shows significant fluctuations in standard deviation, decreasing in the 2020 curriculum and increasing in the 2024 curriculum, likely due to major changes in course scope and CLOs. In Linear Algebra, the standard deviation consistently increases, possibly due to the restructuring of the course and increased credit weight under the 2020 and 2024 curricula. Calculus 2 saw a decline in standard deviation under the 2020 curriculum, while Introduction to Data Science had the lowest standard deviation in the 2020 curriculum, indicating more consistent grades. Mathematical Statistics showed slight instability, with a small increase in standard deviation in the 2020 curriculum, likely due to reduced credit weight and changes in CLOs. Overall, these findings suggest that curriculum changes impact grade distribution differently across courses, which may signal curriculum effectiveness. As a next step in understanding the impact of curriculum changes on students' academic performance, visualisation analyses were conducted on the average grades and pass rates for each curriculum across the five core courses.

6. Average Grades and Pass Rates for Introduction to Data Science and Mathematical Statistics

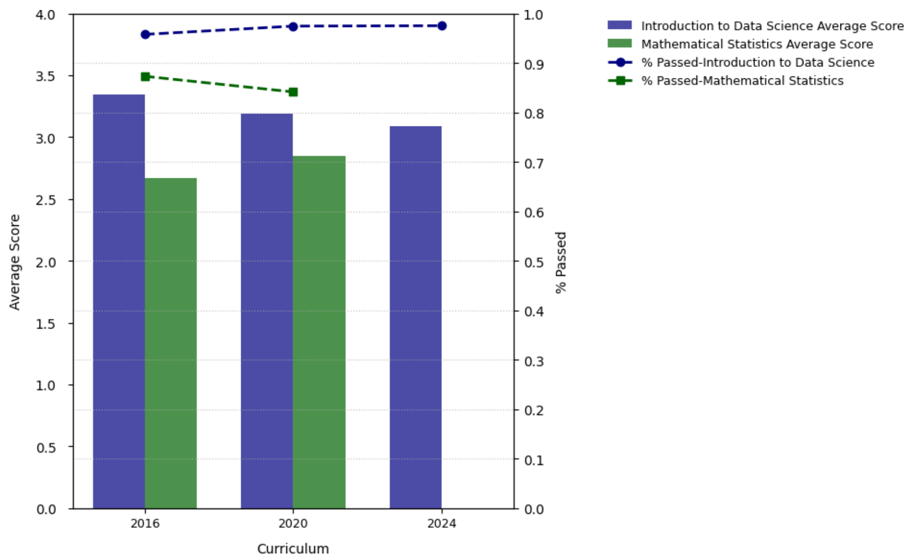

Figure 4. Academic Performance Comparison vs Mathematical Statistics

The chart reveals contrasting performance trends between Introduction to Data Science and Mathematical Statistics, two courses with overlapping statistical content but differing outcomes. For Data Science, average grades declined from 3.35 (2016) to 3.09 (2024), yet pass rates rose steadily (95.75% to 97.5%), likely due to task-based evaluations and flipped classrooms accommodating expanded content like big data and AI. Conversely, Mathematical Statistics saw average grades rise (2.67 to 2.85 by 2020) but pass rates drop (87.29% to 84.12%), suggesting that while active learning methods improved outcomes for persistent students, added complexity (e.g., multivariate distributions) created barriers for others.

These divergences may stem from pedagogical and structural differences. *Data Science* employs flexible assessments that prioritize practical application, enabling students to adapt despite growing material difficulty. In contrast, Mathematical Statistics emphasizes theoretical depth. While active learning elevates grades for engaged learners, its heavier conceptual demands disproportionately affect pass rates. Both courses evolved toward applied approaches, but their assessment strategies and content scope adjustments yielded distinct trade-offs between rigor and accessibility.

A critical factor is course timing and workload. Data Science, positioned earlier in the academic journey, benefits from students' initial motivation and lighter overall credit loads, fostering higher pass rates even as grades dip. Mathematical Statistics, placed later with higher credit weight (3–4 vs. two credits), coincides with intensified academic pressures, amplifying challenges despite improved grades. This highlights how semester placement and workload balance shape outcomes, even for courses with similar content.

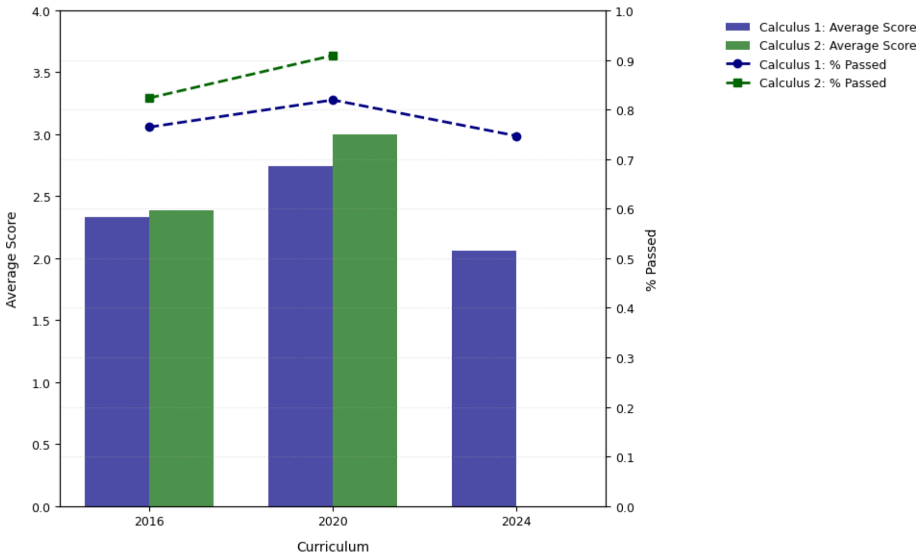

Figure 5. Academic Perfomance Comparison Calculus 1 vs Calculus 2

7. Average Grades and Pass Rates for Calculus 1 and Calculus 2

The chart highlights contrasting performance trends between Calculus 1 and Calculus 2, sequential courses with progressively advanced material. For Calculus 1, average grades rose initially from 2.33 (2016) to 2.74 (2020) but sharply declined to 2.06 in 2024, while pass rates peaked at 81.93% before dropping to 74.68%. This decline correlates with curriculum shifts emphasizing real-world applications, inquiry-based learning, and intensive assessments (e.g., concept presentations), increasing student complexity. Conversely, Calculus 2 showed steady improvement, with grades rising from 2.39 (2016) to 3.00 (2020) and pass rates climbing from 82.32% to 90.91%, despite covering more advanced topics like multivariable functions and parametric transformations.

The disparity suggests differences in student adaptability. Calculus 2 benefits from streamlined evaluation structures and blended learning (theory-practice balance), aiding comprehension of complex content. In contrast, Calculus 1's 2024 struggles reflect challenges balancing active learning methods (flipped classrooms, practical assignments) with foundational adjustments to university-level demands. While both courses adopted applied approaches, Calculus 1's escalating workload and conceptual shifts coincided with students' initial transition phase, whereas Calculus 2 maintained stable credit weight three and leveraged prior student acclimatization.

A key explanation lies in course sequencing and timing. Calculus 1, positioned earlier in the academic journey, coincides with students' adjustment to self-directed learning and academic pressures, amplifying difficulties despite its foundational role. Calculus 2, taken later, builds on this groundwork, allowing students to apply strengthened study habits and resilience to its advanced material. This sequential structure clarifies the paradox: While Calculus 2 is more complex, students' improved preparedness after overcoming first-semester challenges enables higher performance, underscoring the critical role of transitional support in foundational courses.

8. Average Grades and Pass Rates for Linear Algebra

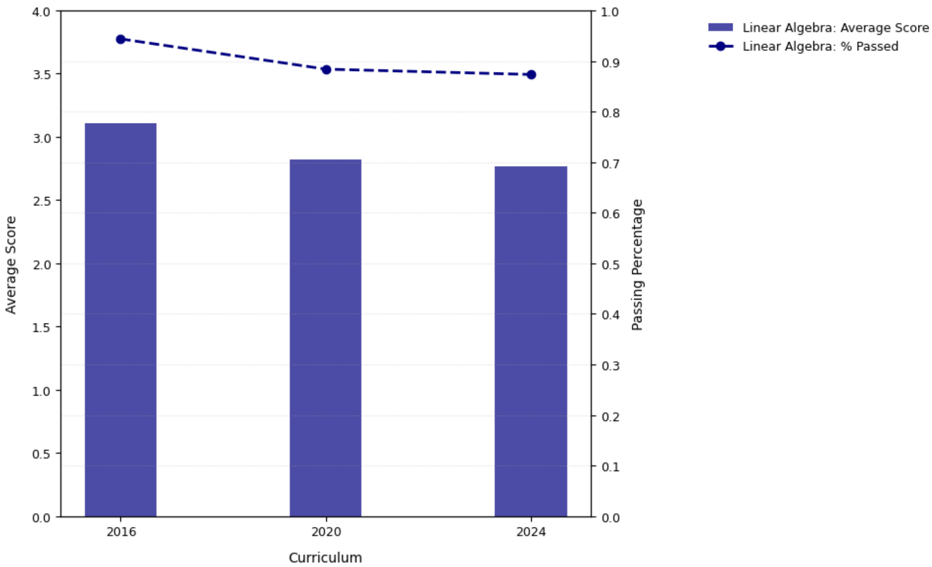

Figure 6. Academic Performance of Linear Algebra

The Linear Algebra course experienced a consistent decline in average grades, from 3.11 in 2016 to 2.825 in 2020 and further to 2.77 in 2024. Similarly, the pass rate decreased from 94% in 2016 to 88.39% in 2020 and 87.34% in 2024. The course credit weight also changed over time. In 2016, Linear Algebra was offered as a single 3-credit course. By 2020, it was split into the Elementary Linear Algebra and Linear Algebra 1 courses. The Course Learning Outcomes (CLOs) expanded during this period. In 2020, the curriculum introduced more in- depth coverage of linear transformations, and in 2024, it will be further extended to include applications of linear algebra in computer modeling. The teaching methods evolved from traditional lectures in 2016 to an active learning approach based on discussions and conceptual presentations in 2020. By 2024, the course had become more programming-oriented, incorporating tools such as MATLAB and Python. Assessment methods also shifted significantly—from written exams to coding-based assignments, which posed more significant challenges for students and likely contributed to declining average grades and pass rates. These changes reflect increased complexity in both content and assessment, demanding higher levels of abstraction, computational skills, and independent learning from students.

Through the analysis of the curriculum changes in 2016, 2020, and 2024, it is evident that each curriculum has different impacts on students' academic performance, although each has its own characteristics and challenges. The quality of teacher professional development, as noted by Richter & Richter (2024), plays a crucial role in ensuring that pedagogical changes are effectively implemented, with a focus on active learning approaches and relevant content. Overall, while various changes in curriculum aspects may add complexity, adapting to students' needs and continuous improvement in teaching remain key to supporting academic success.

D. CONCLUSIONS AND SUGGESTIONS

This study concludes that curriculum changes in mathematics—though designed to modernise learning through integration of AI, big data, and applied competencies—can simultaneously introduce academic challenges when the complexity of content and assessment methods exceeds student readiness. The findings reveal that while some curriculum reforms (e.g., the 2020 revisions) foster improved student outcomes, others (notably in 2024) correlate with declining grades and lower pass rates in key courses such as Calculus 1 and Linear Algebra. These patterns suggest that successful curriculum implementation requires not only content innovation but also robust pedagogical scaffolding.

The main contribution of this research lies in its identification of specific curriculum components such as course learning outcomes, credit allocation, and evaluation methods that influence student academic performance. These insights provide a valuable basis for evaluating and refining curriculum frameworks in higher education mathematics programs. One limitation of this study is the exclusive reliance on final grade data without incorporating student demographic profiles, classroom-level instructional variables, or qualitative feedback from educators and learners. Additionally, the analysis did not extend to statistical hypothesis testing or predictive modelling, which could strengthen causal interpretations. To improve future curriculum reforms, it is recommended that policy designers prioritise transitional support mechanisms, including structured mentorship programs, gradual content integration, and balance between theoretical and applied learning. Further research should explore the longitudinal impact of these changes using mixed-methods approaches to capture the lived experiences and adaptation strategies of both students and instructors.

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