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Enhancing Academic Performance: A Quasi-Experimental Study on Digital Periodical Challenge Tests

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ABSTRACT

Innovative teaching methodologies continually shape the landscape of learning and enhancing student learning outcomes remains a paramount goal. This research paper explores an intriguing dimension of pedagogical advancement by investigating the transformative impact of Digital Periodical Challenge Tests (DPCTs) concerning students' overall academic performance. This research proposes DPCTs as a bridge between these two concepts, providing continuous feedback and opportunities for students to refine their understanding and demonstrate their knowledge in real-time. Two distinct groups were identified i.e., one exposed to the dynamic regimen of DPCTs and the other navigating conventional learning pathways. A chi-square test was deployed to perform the analysis by conducting a comparative analysis leveraging a Quasi-Experimental design. The findings indicate that the incorporation of DPCTs significantly influenced student performance. The findings offer a fresh perspective, underscoring the potential of challenge-driven learning to spark motivation, enhance engagement, and catalyze enduring intellectual growth and knowledge retention. Aligning with the direction towards the quality of education highlighted in Sustainable Development Goal 4 (SDG4), this research recommends the integration of DPCTs in educational settings to enhance student academic performance significantly. The findings underscore the transformative impact of DPCTs, promote cognitive skills, and improve performance on conventional assessments, demonstrating their effectiveness in bridging the gap between learning and performance. Educators are encouraged to explore and implement DPCTs as a valuable strategy for optimizing learning outcomes and enriching the overall educational experience.

Keywords: Digital tests, Quasi-experimental design, academic performance, chi-square test, pedagogical advancement

INTRODUCTION

In the contemporary landscape of education, where pedagogical concepts persistently develop, the quest for innovative approaches to enhance student learning outcomes remains vital. Innovative learning approaches, such as problem-based, blended, gamification, and flipped learning, have positively impacted student motivation, engagement, and critical thinking skills (Manju et al., 2023). This research explores the connection between cognitive empowerment and pedagogical initiative through an exploration of formative assessments i.e., DPCTs, and their great impact on student performance. As educational methodologies transcend conventional boundaries, the investigation needs to sort out the transformative potential of DPCTs in reshaping the trajectory of academic achievement.

With a keen focus on preparing students for final exams, this research investigates the cultivation of resilient study habits and focused knowledge assimilation facilitated by DPCTs. The inquiry aims to reveal a multi-dimensional perspective on academic effectiveness through a precise comparative analysis between two distinct student groups—one exposed to the dynamic regimen of DPCTs and the other following conventional pathways. Although devoid of direct student feedback, the research employs rigorous empirical examination to provide nuanced insights into the sophisticated interplay between challenge-driven learning and cognitive enrichment. As educators and stakeholders navigate uncharted teaching territories, this research sets the stage for reimagining pedagogical strategies and connecting the potential of DPCTs to propel students toward unexplored realms of intellectual accomplishment.

Problem Statement

The pursuit of innovative teaching methods that notably boost student performance and engagement remains a persistent priority in education. Various studies emphasize the importance of implementing innovative approaches, such as problem-based learning, blended learning, and flipped classrooms, to enhance student motivation, critical thinking skills, and academic achievement. (Swapnali et al., 2022). However, despite advancements in pedagogical techniques, there remains a notable gap in understanding the specific impact of DPCTs on students' academic achievement, particularly in inherently challenging subjects, such as mathematics. The existing body of research lacks comprehensive empirical studies that evaluate the transformative effects of DPCTs on final exam preparation and overall academic performance. This lack of research delays the development of effective and informed pedagogical strategies that could potentially control the benefits of DPCTs. Specifically, the absence of robust evidence prevents educators from fully understanding how DPCTs influence students' study needs, engagement, and performance in high-stakes assessments.

Furthermore, limited studies employ a quasi-experimental design to explore the relationship between DPCTs and students' comprehension levels across diverse learning environments. Such a methodological approach is crucial for isolating the effects of DPCTs from other variables and gaining a clearer picture of their efficacy. The current lack of evidence-based research on DPCTs poses a significant barrier to optimizing teaching strategies in mathematics-based subjects. Without a detailed understanding of how DPCTs impact student learning and exam readiness, educators are unable to make data-driven decisions that could enhance educational outcomes. Addressing this gap through targeted research is essential for developing pedagogical approaches that leverage the full potential of DPCTs, ultimately leading to improved academic achievement in mathematics and other challenging disciplines.

Research Questions

This research aims to explore the impact of DPCTs on student performance and learning behaviors. The research is guided by the following questions:

i. What is the significance of DPCTs in fostering effective preparation for final exams?

This question seeks to investigate how participation rates, scores, and self-reported study habits of students exposed to DPCTs contribute to focused and consistent study practices, potentially enhancing performance in high-stakes assessments.

ii. How does the final exam performance of students exposed to DPCTs compared to that of a control group not subjected to DPCTs?
This question aims to utilize rigorous statistical analysis to determine whether students who undergo DPCTs demonstrate superior final exam performance compared to those who do not.

iii. How does the overall academic performance of students exposed to DPCTs compare to that of a control group?
This question examines the broader academic performance of both groups, encompassing final exam scores, formative assessments, DPCTs, and continuous assessments to provide a comprehensive comparison of their academic achievements.

Research Objectives

This research sets out the following objectives to systematically investigate the impact and effectiveness of DPCTs on student performance. These objectives aim to provide a clear framework for evaluating the role of DPCTs in enhancing academic outcomes:

i. To evaluate the impact of DPCTs on student preparation for final exams.
ii. To compare the final exam performance of students exposed to DPCTs with a control group not subjected to DPCTs.
iii. To compare the overall academic performance of students exposed to DPCTs with that of a control group.

Literature Review

Formative assessment plays a significant role in influencing the outcome of summative exams. It helps identify students' learning gaps and provides feedback to fill those gaps, inspiring deep learning, and regular study (Das et al., 2017). Administering formative tests that align with the regular class sessions, such as group assessments or representative assessments, can enhance student engagement and learning (Tamah & Wirjawan, 2019) Introducing e-assessment into teaching has shown improved passing rates in final practical exams, and neural networks can be used to model the correlation between e-assessment results and final test success (Gamulin et al., 2015). Formative assessment, particularly through feedback, is crucial for developing students' learning and learning-to-learn competence. It involves setting learning goals, assessing learning progress, and using mistakes as opportunities for learning (Voinea, 2018). These digital assessments provide instant feedback, helping students to self-regulate their learning while identifying specific areas for improvement (Lai et al., 2022). Studies have demonstrated that frequent, low-stakes digital formative assessments not only reduce student anxiety but also increase motivation and improve overall academic performance by reinforcing key concepts (Jensen et al., 2021). The DPCTs, specifically, have been shown to foster higher order thinking skills by regularly challenging students with progressively complex questions, while also providing the flexibility for students to learn at their own pace. This self-paced learning combined with timely feedback encourages deeper understanding and retention of the material (Nguyen et al., 2021). Formative assessment, particularly through feedback, remains crucial for developing students' learning and learning-to-learn competence. It involves setting learning goals, assessing learning progress, and using mistakes as opportunities for learning (Voinea, 2018). Digital platforms enable more detailed and personalized feedback, making it easier for educators to monitor and address individual student needs, thus enhancing the effectiveness of the assessment (Harrison & Wass, 2020). Furthermore, there was an investigation on the effectiveness of Hebdomadal Challenge Tests (HCT) as a digital pedagogical tool to enhance cognitive skills in a 10-week classroom study by (Azami & Sireesha, 2024).

Studies have shown that there is a positive relationship between formative assessment data and summative data in mathematics classrooms for primary-grade learners (Wang et al., 2021). This relationship is stronger in classrooms where students have lower average performance on the formative assessment data (Connors, 2021). Additionally, the implementation of a reformed formative assessment system has been shown to improve the quality of pathophysiology education, as evidenced by the positive relationship between formative and summative assessment scores (Cong et al., 2020). Furthermore, the word association test (WAT) is an effective formative assessment tool, leading to conceptual change and development in students' minds (Çetinkaya et al., 2020). Continuous assessments have been found to have a positive correlation with final exam grades (Abdur-Rafiu et al., 2020; Rogaten et al., 2020). Several studies have shown that students who perform well in continuous assessments tend to perform well in exams (Leppink, 2020; L. Wang et al., 2019). In one study, a significant relationship was found between students' continuous assessment scores and their performance in both NECO and WASSCE exams (Nagandla et al., 2018). Students' active involvement in in-class activities has a significant impact on their final exam grades (Cormier & Voisard, 2018). Implementing active pedagogy, such as the flipped classroom approach, can increase students' achievement in difficult courses like organic chemistry (Ashenafi et al., 2015). Similarly, the use of clicker quizzes as in-class activities has been shown to improve academic performance (Priego-Quesada et al., 2019). These quizzes provide real-time results, increase student engagement, and make the classroom more interactive. Further, the use of game-like mechanics in challenge tests, such as leader boards and achievement badges, has been found to increase student motivation and active participation, resulting in better learning outcomes (Domínguez et al., 2019). Overall, the evidence suggests that students' active participation in in-class activities can positively impact their final exam grades.

Quasi-experimental designs serve as valuable alternatives to randomized control trials (RCTs) in research scenarios where RCTs are not feasible or ethical (Cham, H., 2022). These designs, such as regression discontinuity and interrupted time series designs, offer strong internal validity when certain assumptions are met (Cham, H., 2022) (Souza, M., 2022). Quasi-experimental research is particularly useful in applied psychology, education, and other fields where experimental research may not be practical (Singh, A., 2021). Quasi-experimental designs, particularly those utilizing chi-square tests, are increasingly employed in educational research to assess the effectiveness of various teaching methods. Chi-square test commonly used used in quasi-experimental designs to analyze categorical data, helping to determine if there are significant differences in outcomes between groups, as seen in studies assessing educational interventions (Rogers & Révész, 2019), (Rambachan & Roth, 2024).

METHODOLOGY

This research employs a structured approach to investigate the impact of DPCTs on student performance towards learning mathematics in Asia Pacific University, Malaysia. This study sampled a population of undergraduate students from academic year 2023 (September intake), degree level 1, first semester core mathematics module with module code, AQ010-3-1-MCFC: Mathematical Concepts for Computing (MCFC) was chosen over a period of 14 weeks. This module introduces basic computing mathematical concepts that are needed for their further study in degree level 2. This module is designed to elaborate the relationship and interdependence of mathematics & computing. The topics that are included in this module are Number Base System, Set Theory, Relations & Functions, Discrete Probability, Logic & Boolean Algebra and Graphs & Trees.

Research Design

The flowchart in **Figure 1** visually represents the research design of the study, which employs a quasi-experimental approach to evaluate the impact of DPCTs on student performance in the MCFC module. This research employs a quasi-experimental design to assess the impact of DPCTs on students' performance in the MCFC module. A quasi-experimental design is chosen due to practical constraints that prevent random assignment of participants. Two distinct groups are identified: a control group and an experimental group. Participants are assigned to groups based on their class enrolment. One class is designated as the control group, where conventional teaching methods are employed, while the other class serves as the experimental group, incorporating DPCTs as a teaching pedagogy. The dependent variable is students' performance in the MCFC module, measured by their overall grades.

The independent variable is the teaching pedagogy, categorized into two levels:

i. **Control Group:** Conventional teaching methods
ii. **Experimental Group:** DPCTs as supplementary teaching and learning pedagogy.

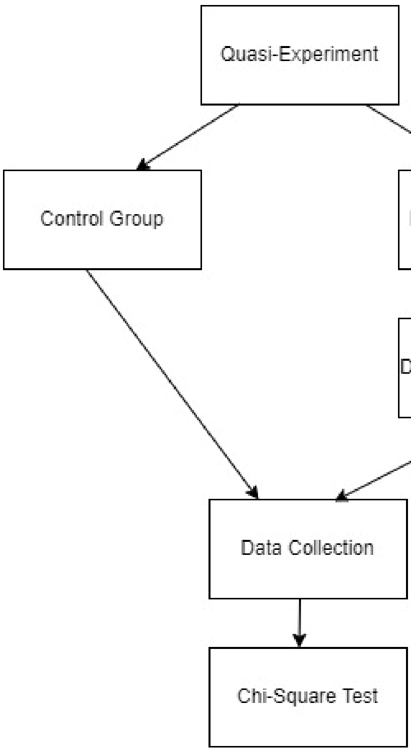

Figure 1: Research Design

Students' overall grades in the MCFC module are collected at the end of the academic term. Performance data include continuous assessments, such as Test 1, Test 2, and the Final Exam. To enhance the internal validity of the study, consistent efforts are made to control variables other than the teaching pedagogy. Lecture slides, tutorial questions, lecture and tutorial hours, and assessments are maintained consistently across both groups. For the experimental group, data related to the implementation of the DPCTs were collected five times throughout the academic term. This includes details on test design, topics covered, and student engagement.

Participants

The participants involved in this research are first-year students enrolled in the MCFC module, a core course offered across all Bachelor of Science (Honours) computing and technology programs at APU in Malaysia during the second semester. The student population reflects APU's global character, comprising individuals from various countries. Approximately 65% identified as local students, while 35% hailed from international backgrounds. Students entered the program with diverse academic qualifications, including A-Level, SPM, AUSMAT, STPM, Matriculation, and Foundation programs. This resulted in varying levels of prior knowledge in fundamental mathematics skills. The study's participants comprised students who were actively enrolled in two different lecture groups Group 1 and Group 2 of the MCFC. There was a total of 495 students registered with this module from different programmes.

Experimental Group

Lecture Group 1 assumed the role of the experimental group, engaging in a dynamic learning journey augmented by the implementation of five DPCTs. Aligned meticulously with the sequential progression of covered lectures, the DPCTs mirrored the thematic domains of Logic Algebra, Boolean Algebra, Proof Techniques, Graph Theory, and Trees, respectively. Each DPCT was thoughtfully curated to evaluate a spectrum of cognitive dimensions, including students' comprehension prowess, critical thinking, numeracy proficiency, and aptitude for applied knowledge—an adept preparation for the impending summative assessment, the final exam. The administration of these DPCTs took place within the tutorial class immediately following the culmination of the relevant lecture, facilitating a seamless integration of challenge-based evaluation into the pedagogical continuum.

Control Group

Lecture Group 2 was designated as the control group, devoid of any Digital Periodical Challenge Test (DPCT) intervention. This deliberate absence of DPCTs served the pivotal purpose of establishing a foundational benchmark for gauging student performance and learning outcomes. The control group's role encompassed capturing the existing state of academic achievement and knowledge attainment before any external influences, thus providing a reference point against which the impact of the intervention could be assessed.

Data Collection

All DPCTs were conducted through Microsoft Forms, an online assessment platform that ensures standardized test delivery. Each student was provided with a unique link to access the tests, allowing for controlled administration and data collection. Microsoft Forms facilitated a consistent testing environment by automatically logging responses, timestamps, and individual completion times. This approach not only maintained the integrity and security of the assessment process but also enabled efficient data management and analysis. The platform’s features allowed for real-time monitoring of test participation and performance metrics, ensuring that all collected data was accurate and reliable for subsequent analysis. This methodology supported the study's goal of evaluating the impact of DPCTs on student performance in a structured and systematic manner.

Statistical Analysis

A frequency distribution of the student's performance has been examined based on their grade score. The statistical analysis employs the Chi-square test to determine the significant association between the teaching pedagogy and students' performance. The Chi-square test is selected due to its suitability for analyzing relationships between categorical variables. This test will help assess whether there is a statistically significant difference in performance outcomes between the control group, which uses conventional teaching methods, and the experimental group, which incorporates DPCTs.

Hypothesis

The hypothesis statement sets up the framework for testing whether the introduction of DPCTs has a statistically significant impact on the performance of students in the MCFC module. The null hypothesis assumes no association, while the alternative hypothesis posits the presence of a significant association. The statistical analysis, particularly the Chi-square test, will be used to evaluate and determine the support for one of these hypotheses based on the collected data.

i. **Null Hypothesis (H0):** There is no significant association between the teaching pedagogy (use of DPCTs) and students' performance in the MCFC module.

ii. **Alternative Hypothesis (H1):** There is a significant association between the teaching pedagogy (use of DPCTs) and students' performance in the MCFC module.

The methodology employed in this study reflects a meticulous approach to investigating the effects of DPCTs on student performance within the MCFC module. The study's design and execution are guided by the overarching goal of comprehensively assessing the potential influence of challenge-driven learning on academic achievement.

RESULTS

The results of this study aim to compare the academic performance of students in the Control Group, who did not receive Digital Periodical Challenge Tests (DPCTs), with those in the Experimental Group, who were exposed to this innovative teaching intervention. By categorizing students' grades, this section provides insights into the effectiveness of DPCTs in promoting higher academic achievement. A frequency distribution analysis of the students' grades, along with a chi-square test for statistical significance, highlights the differences in performance between the two groups. This analysis will help determine whether the intervention significantly impacted students' ability to achieve higher grades and reduce failure rates.

Frequency Distribution

In total, 495 students were grouped into two categories: the Control Group and the Experimental Group, to assess their performance based on their grades. The performance of the students was categorized by the following grade scale: A+, A, B+, B, C+, C, C-, D, and F.

Table 1 shows the frequency distribution of the student's grade. The Control Group consisted of 167 students. A higher proportion of students received A+ (58 students), while fewer students were graded as F (22 students). The distribution of other grades followed a fairly even spread, with a slight increase in D and F grades. The Experimental Group, which comprised 325 students, showed a significant concentration of A+ grades, with 176 students achieving this highest mark. In contrast, only 7 students received an F grade. Other grades such as A (35 students), B+ (32 students), and B (18 students) were also observed in moderate numbers, while the lower end of the scale (C-, D, F) had fewer students. Total across both groups, 492 students were evaluated based on their performance. The most frequent grade awarded was A+ (234 students), indicating a larger number of high performers, especially in the experimental group. On the other hand, the F grade was the least common, with 29 students across both groups.

Table 1: Students Overall Grade

	A+	A	B+	B	C+	C	C-	D	F	Total
Control Group	58	17	14	11	11	9	10	15	22	167
Experimental Group	176	35	32	18	15	10	18	14	7	325
Total	234	52	46	29	26	19	28	29	29	492

The bar chart in **Figure 2** illustrates the distribution of students' overall grades comparing the control group (blue bars) and the experimental group (orange bars). This visual representation is based on Table 1.

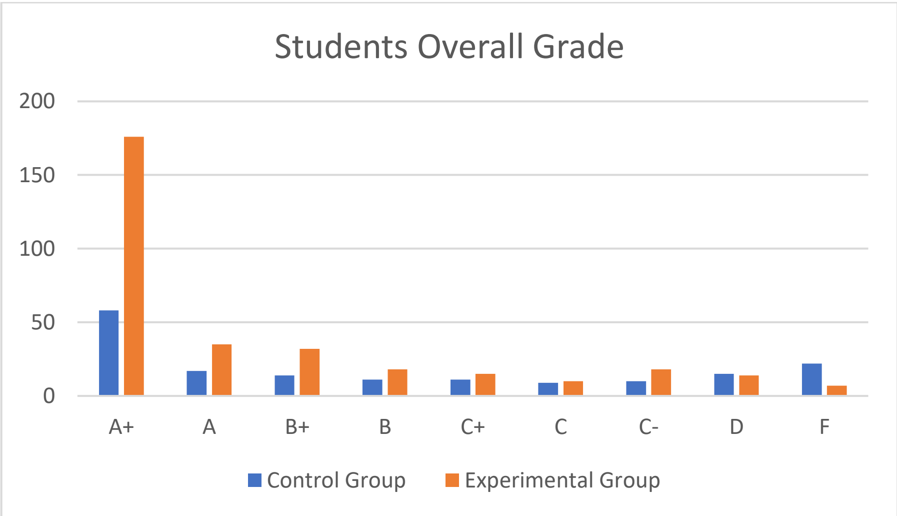

Figure 2: Students Overall Grade

Based on Figure 2 the Experimental Group had a significantly higher number of students achieving an A+, with around 176 students, compared to only 58 in the Control Group. Similarly, the Experimental Group outperformed the Control Group for other high grades, such as A, B+, and B, though the difference was less pronounced. For instance, 35 students in the Experimental Group received an A, compared to 17 in the Control Group, while 32 Experimental Group students earned a B+, compared to 14 in the Control Group. In the middle grade categories (C+, C, C-), the Experimental Group maintained a slight advantage, though both groups had fewer students in these categories. Notably, in the lower grades, the Control Group had a higher number of students receiving D and F grades. The Control Group had 22 students with an F, while the Experimental Group had only 7, reflecting a lower failure rate in the Experimental Group. This distribution suggests that the intervention applied in the Experimental Group led to better overall performance, with more students achieving higher grades and fewer failing compared to the Control Group.

Chi-square Analysis

The Chi-square test was employed to investigate the potential association between the use of the DPCTs as a teaching pedagogy and students' performance. The test produced a significant result with a chi-square statistic of 38.439 and a corresponding p-value of 6.244×10^{-6}, indicating a highly statistically significant association between the implementation of DPCTs and student performance. The calculated chi-square test statistic of 38.439 underscores the strength of the observed relationship between teaching pedagogy and student outcomes. The low p-value, significantly below the common significance threshold of 0.05, provides compelling evidence to reject the null hypothesis, which posited no significant association between the use of DPCT and student performance.

DISCUSSION

The findings of this study provide compelling evidence that DPCTs significantly enhance student performance in the MCFC module, directly addressing the research objectives. By employing a quasi-experimental design, the study successfully compared the performance of students exposed to DPCTs with those subjected to conventional teaching methods. The statistical analysis, specifically the Chi-square test, revealed a highly significant association between the use of DPCTs and improved student performance. The results indicate a marked difference in performance between the control and experimental groups. Students in the experimental group, who were taught using DPCTs, consistently achieved higher grades compared to their counterparts in the control group. The Chi-square test yielded a statistic of 38.439 and a p-value of 6.244×10^{-6} , far below the significance threshold of 0.05. This strong statistical evidence allows us to confidently reject the null hypothesis, supporting the presence of a significant association between the implementation of DPCTs and enhanced student performance.

CONCLUSION

These findings underscore the effectiveness of DPCTs as a pedagogical tool in promoting better academic outcomes. DPCTs promoted focused and consistent study habits, contributing positively to overall performance in continuous assessments and final exams. The experimental group not only excelled in final exams but also showed improved performance across broader academic performance indicators, underscoring the comprehensive benefits of DPCTs. In conclusion, the study provides strong evidence supporting the adoption of DPCTs in mathematics-based subjects to enhance student performance. The significant improvements observed in the experimental group highlight the potential of DPCTs to transform teaching and learning processes, making them an invaluable addition to contemporary educational strategies. Future research should continue to explore the broader applicability of DPCTs across various disciplines and educational settings to further validate these findings and optimize pedagogical practices.

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