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Assessment of Cognitive Skills: Hebdomadal Challenge Tests as a Digital Pedagogical Tool

Abstract: - This research investigates the effectiveness of Hebdomadal Challenge Tests (HCT) as a pedagogical tool to enhance cognitive skills in a 10-week classroom study. The study consists of two distinct phases: a five-week baseline period without any HCT, followed by five weeks of HCT aligned with lecture topics. Pre-intervention and post-intervention summative assessments were conducted to measure the effects of the HCT on student learning outcomes, including comprehension, critical thinking, numeracy skills, and application of knowledge in computing-based applications. Due to the abnormality of the data, a non-parametric test, Wilcoxon signed-rank test was conducted and employed to identify the significant differences in performance between the pre-intervention and post-intervention scores. R scripts were deployed to perform the analysis. The findings indicate that the incorporation of HCT influenced significantly on certain students' learning outcomes. Students demonstrated an improvement performance in the post-intervention summative assessment compared to their pre-intervention scores. These results suggest that the regular implementation of HCT aligned with lecture topics facilitated a deeper understanding and retention of the subject matter. The inclusion of regular challenge tests as a pedagogical tool actively engaged students, promoted continuous learning, and reinforced key concepts, preparing them for upcoming assessments. In conclusion, this research highlights the positive impact of HCT on student learning outcomes. By incorporating regular assessments that encourage critical thinking and problem-solving skills, educators can create a more comprehensive and meaningful learning experience. Further investigation and implementation of similar assessment strategies are encouraged to optimize learning outcomes.

Keywords: Cognitive Skills; Pedagogical Tool; Students' Performance; Hebdomadal Challenge Tests; Wilcoxon Signed-Rank Test

I. INTRODUCTION

Traditional assessments, such as end-of-unit exams or standardized tests, provide insights into students' learning progress. However, they often fail to capture the full extent of students' comprehension and long-term retention of the material. Research in educational psychology has highlighted the importance of frequent and distributed practice in promoting meaningful learning and knowledge retention. This has led educators to explore alternative assessment strategies that can foster deeper understanding and improve long-term retention of subject matter. The significance of this study lies in its potential to inform educational practices and enhance learning outcomes. By investigating the effectiveness of hebdomadal challenge tests as a pedagogical tool, this research addresses the need for innovative assessment strategies that promote active learning, critical thinking, and subject matter retention.

The findings from this study can contribute to evidence-based practices in education, providing insights for educators on how to engage students, tailor instruction, and foster deeper understanding. Furthermore, the study's focus on a diverse student population with varying pre-university qualifications adds to its significance, as it highlights the importance of inclusive and differentiated approaches to education.

In today's educational landscape, the importance of effective assessment strategies cannot be overstated. Assessments serve as valuable tools for measuring students' knowledge, skills, and understanding of academic concepts. Educators constantly seek innovative approaches to enhance learning outcomes and improve student performance. One such approach that has gained attention is the implementation of hebdomadal challenge tests as a pedagogical tool. These Hebdomadal Challenge Tests (HCT) are designed to assess students' cognitive skills and their retention of subject matter in an academic setting. The pre-intervention score refers to the assessment of the outcome of students' Test 1 (T1) scores before the intervention is implemented i.e., HCT. It represents the initial level of knowledge before any intervention has taken place. The post-intervention score, on the other hand, refers

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to the assessment of the outcome of students' Test 2 (T2) scores after the intervention has been implemented i.e., HCT. It represents the level of knowledge after the intervention.

The objectives of this research are (1) to explore the relationship between the performance of students in pre-intervention and post intervention assessments, (2) to investigate the relationship between the performance of students in pre-intervention and post intervention assessments. The research questions are (1) What is the extent of the significant relationship between the performance of students in pre-intervention and post intervention assessments. (2) How does the performance of students in post intervention assessment relate to their performance in the HCT.

Several studies have investigated the effectiveness of implementing regular assessments, such as HCT, to enhance learning outcomes in a classroom setting. Research in the field of cognitive psychology and educational assessment has highlighted the potential benefits of such assessments in promoting student engagement, knowledge acquisition, and critical thinking skills.

A. Theoretical Framework

The current study investigates the effectiveness of implementing HCT as a pedagogical tool to enhance learning outcomes in a classroom setting. This section provides a theoretical foundation for understanding the impact of regular assessments on student engagement, knowledge acquisition, and critical thinking skills. It draws on the concepts of spaced retrieval practice, formative assessment, and the benefits of frequent testing as powerful learning tools.

B. Previous Research on Classroom Assessment

The implementation of HCT has a positive influence on the long-term retention of subject matter among students, as measured by the difference between pre-intervention (Test 1) and post-intervention (Test 2) assessment scores. The use of role-modeling clinical skills and professional behavior through pre and post-tests is an effective teaching strategy for fourth-year medical students (Machowska et al., 2020). Additionally, a web-based brief alcohol intervention called What Do You Drink (WDYD) has been found to sustain a reduction in alcohol use among heavy-drinking students at 1-, 3-, and 6-month follow-up intervals (Kini et al., 2018).

Studies have demonstrated that the use of role-modeling interventions, such as modeling clinical skills and professional behavior, can significantly improve learning outcomes for medical students as measured by pre and post-test assessment scores (Khan et al., 2021). Additionally, web-based interventions, such as the What Do You Drink (WDYD) program, have been effective in sustaining a reduction in alcohol use among students at 1-, 3-, and 6-month follow-up intervals (Niazi & Khaliq, 2022).

The use of a multidisciplinary, collaborative, multisectoral, and trans-disciplinary approach in workshops on One Health and the indigenous people of peninsular Malaysia called the Orang Asli resulted in a significant increase in knowledge and interest concerning One Health and the Orang Asli (Rashid & Lau, 2020). A brief video intervention on reproductive health and infertility increased knowledge of fertility issues, infertility risk factors, and the definition of infertility among young adults (Conceição et al., 2017). However, there is no specific information available regarding the influence of hebdomadal challenge tests on long-term retention of subject matter among students as measured by pre-intervention and post-intervention assessment scores (Purkiss et al., 2021).

The perceived benefits of incorporating HCT from the perspectives of educators and students include improved knowledge and understanding of the subject matter, increased engagement and motivation, and the opportunity to identify areas of weakness and address them effectively (Bullock et al., 2017). In addition, from the perspectives of both educators and students include improved self-esteem, academic confidence, and performance (Omari et al., 2023). However, there are also challenges associated with HCT implementation. These challenges include the need for adequate preparation and planning, potential stress and anxiety for students, and the need for effective feedback and support from educators (Indracanti et al., 2021). Despite these challenges, the effectiveness of the intervention is influenced by factors such as educators' perceptions of their preparation programs, the strengths and weaknesses of school leadership, and the encouragement to collaborate with others in the educational community (Xue et al., 2021). Additionally, the year of study and academic performance of students can also impact the effectiveness of HCT implementation (Netanda et al., 2020).

Students reported feeling more confident to participate in class without intimidation, improved IT literacy, and increased self-esteem and academic performance. Educators observed that HCT fostered cognitive strategies for problem-solving, positive perceptions of problem-solving competence, and enhanced emotions and emotion regulation (Hanin et al., 2021). Additionally, the intervention improved students' capability and motivation for handwashing, as well as their handwashing knowledge and skills (Okello et al., 2019).

The performance of students in HCT is shown to be improved compared to traditional assessments in terms of promoting active learning, critical thinking, and overall comprehension of academic concepts (Freeman et al., 2014; Hajhosseini et al., 2016; Nelson & Crow, 2014). Active learning strategies have been found to increase examination scores and decrease the likelihood of failure in STEM disciplines (Al Ansari et al., 2021). Additionally, active learning approaches have been shown to improve critical thinking ability and problem-solving skills in pre-service teachers (Cardozo et al., 2020). Furthermore, the use of active learning methodologies has been associated with lower levels of stress and anxiety among students, leading to improved performance in exams.

The effectiveness of active learning environments on students' understanding of academic concepts has been investigated in several studies. In one study by Güner, an active learning environment was found to be more effective in improving students' understanding of the concept of pressure compared to traditional instruction (Tural, 2020). Another study by Yousef examined the impact of active learning with block and problem-based learning (PBL) on motivation and academic performance in dental students. The results showed that active learning strategies, such as block and PBL, enhanced the motivation and academic performance of dental students (Al-Thomali, 2021). Online learning has become an integral part of today’s educational system, especially after the COVID-19 pandemic (Hashimi et al., 2022).

Demographic factors, such as pre-university qualifications, have been found to influence academic success and learning outcomes among a diverse student population. In a study by Blatt et al., it was found that students' race/ethnicity and parent education level were significant predictors of course grades in introductory STEM courses (Burgos et al., 2022). Another study by Pozo Burgos et al. examined the sociocultural and demographic factors that influence academic performance in a pre-university course. They found that variables such as the educational level of the student's parents and the student's grade on university entrance exams were significant factors in academic success (Rogerson & Rossetto, 2018). However, in a study by Rogerson and Rossetto, it was found that explicit teaching and integrating real-world group situations into class activities can improve learning outcomes and prepare students for a globalized workforce, regardless of their demographic background (Fogarty et al., 2019).

Demographic factors, such as varying pre-university qualifications, can influence the effectiveness of HCT in enhancing learning outcomes and subject matter retention among a diverse student population (Blatt et al., 2020). However, the abstracts provided do not directly address the specific relationship between demographic factors and the effectiveness of HCT in enhancing learning outcomes and subject matter retention, the alignment of instructional materials with diversity-related learning goals in higher education (Ming et al., 2022), the redesign of a challenge-based course to promote interdisciplinary learning experiences (Harrington et al., 2021), the delivery of effective student support and engagement in a regional university (Krzysztofik et al., 2021), and the policies of universities in response to demographic threats in higher education.

Demographic factors, such as varying pre-university qualifications, have a significant impact on the effectiveness of HCT in enhancing learning outcomes and subject matter retention among a diverse student population (Michalski et al., 2017). The literature review reveals that certain groups, including first-generation students, those whose parents did not attend university, Aboriginal peoples, and students with disabilities, are underrepresented in postsecondary education (Refae et al., 2021). These students may face additional barriers in accessing and benefiting from HCT. Additionally, the study conducted in the United Arab Emirates found that demographic characteristics had a significant impact on students' academic performance in both face-to-face (F2F) learning and distance learning (DL). The findings suggest that demographic factors can influence the effectiveness of HCT, and institutions should consider these factors when implementing such tests to ensure equitable outcomes for all students.

C. Benefits of HCT

Several recent studies have focused specifically on the benefits of implementing HCT. Research by Rohrer and Taylor (2018) highlights the positive impact of spaced retrieval practice on long-term retention. Dunlosky et al. (2019) provide insights into the effectiveness of retrieval practice as a learning strategy, including its role in improving comprehension and critical thinking skills. Jang et al. (2021) examine the influence of weekly quizzes on student engagement and performance. These studies collectively emphasize the value of regular assessments, such as HCT, in reinforcing knowledge, strengthening memory retrieval, and enhancing learning outcomes.

D. Gaps in the Existing Literature

While previous research has shed light on the benefits of regular assessments and the effectiveness of HCT there are still gaps that need to be addressed. Firstly, the literature primarily focuses on the impact of assessments on memory retention and comprehension, with limited exploration of other learning outcomes such as creativity and problem-solving skills. Secondly, the majority of studies have been conducted in specific educational contexts or subject areas, warranting further investigation across a wider range of disciplines. Lastly, while there is ample evidence supporting the benefits of assessments, there is a need for more research on the implementation and practical considerations of HCT in diverse classroom settings.

II. METHODOLOGY

By implementing this methodology, the study aimed to evaluate the effectiveness of HCT in promoting deeper understanding, retention of subject matter, and overall improvement in learning outcomes for the students. The results of the analysis will provide insights into the impact of the intervention and contribute to the existing literature on the benefits of regular assessments in educational settings.

A. Research Design

This research utilised an experimental design to examine the effectiveness of HCT in enhancing learning outcomes of the Mathematical Concepts for Computing (MCFC) module by referring to the outcome of T2. The research spanned 10 weeks and consisted of two distinct phases: a pre-intervention phase and a post-intervention phase. The controlling variables such as the same set of assessments, teaching materials, and educators.

B. Participants

The participants in this study were students enrolled in a MCFC module offered for all the BSc (Hons) computing and technology-related programmes in Year 1, semester 2 at Asia Pacific University of Technology and Innovation (APU), Malaysia. The student population in this study is diverse, consisting of students from various countries. The composition of the student body is approximately 65% local students and 35% international students. Furthermore, the students possess a range of admission qualifications, including A-Level, SPM, AUSMAT, STPM, Matriculation, and Foundation programs, etc., resulting in significant variation in prior knowledge of fundamental mathematics skills.

C. Control Phase

The initial five weeks of the study served as the control phase. During this period, no HCT was administered. The purpose of this phase was to establish a baseline measure of student performance and learning outcomes before the intervention.

D. Intervention Phase

Starting from week 6 to week 10, the intervention phase was implemented. HCT aligned with the covered lecture which comprises Counting Principles, Permutation & Combination, and Discrete Probability respectively. The HCT was designed to assess students' comprehension, critical thinking skills, numeracy skills, and ability to apply knowledge in upcoming summative assessments, T2. The HCT was administered during tutorial class following the completion of the corresponding lecture.

E. Data Collection and Analysis

The data collected included performance scores for each participant on these tests. Due to the violation of the normality assumption in the data, a non-parametric test was deployed for the analysis. Specifically, the Wilcoxon signed-rank test was selected. The analysis was conducted in R scripts to generate the output and interpreted. The

Wilcoxon signed-rank test was employed to assess the differences between paired observations. Absolute differences were calculated for each pair for the series of tests. i.e., T1 and T2, T2 and HCT1, T2 and HCT2, T2 and HCT3, HCT1 and HCT2, and HCT2 and HCT3. The use of absolute differences eliminated any positive or negative signs, focusing solely on the magnitude of the differences. The absolute differences were then ranked from smallest to largest, with any time receiving average ranks. Signed ranks were assigned based on the original sign (positive or negative) of the differences. The test statistic for the Wilcoxon signed-rank test was obtained by calculating the sum of the ranks for the positive or negative differences. The study formulated the following hypotheses: the null hypothesis (H0) stating that there is no significant difference between the performance of Test 1, Hebdomadal Challenge Tests, and Test 2, and the alternative hypothesis (H1) proposing a significant difference in performance. The significance level (alpha) was set at 0.05. The general formulation of the hypothesis as follows:

$$H_{ij} = \begin{cases} i, & i = 0,1 \\ j, & j = 1,2,3,4,5,6 \end{cases}$$

where i indicates the null hypothesis denoted as 0, and the alternative hypothesis denoted as 1. For j indicates the paired comparison of these tests.

H_{01} : There is no significant difference between T1 and T2

H_{11} : There is a significant difference between T1 and T2

H_{02} : There is no significant difference between T2 and HCT1

H_{12} : There is a significant difference between T2 and HCT1

H_{03} : There is no significant difference between T2 and HCT2

H_{13} : There is a significant difference between T2 and HCT2

H_{04} : There is no significant difference between T2 and HCT3

H_{14} : There is a significant difference between T2 and HCT3

H_{05} : There is no significant difference between HCT1 and HCT2

H_{15} : There is a significant difference between HCT1 and HCT2

H_{06} : There is no significant difference between HCT2 and HCT3

H_{16} : There is a significant difference between HCT2 and HCT3

The obtained test statistic and the sample size of 213 were utilized to conduct the Wilcoxon signed-rank test. The resulting p-values, which represent the probability of obtaining the observed test statistic or a more extreme value under the null hypothesis, were computed.

III. RESULT

This section indicates the interpretation of the results, implications for classroom practice, and limitations of the study.

A. Interpretation of Results

The Wilcoxon signed-rank test was conducted to examine the performance relationship between T1 and T2, T2 and HCT1, T2 and HCT2, T2 and HCT3, HCT1 and HCT2, and HCT2 and HCT3. The test was chosen as the data did not meet the assumption of normality. A significance level of $\alpha = 0.05$ was used. The absolute differences between the paired observations of each comparison were calculated. These differences were ranked, and signed ranks were

assigned based on the original sign of the differences. The test statistic obtained from the Wilcoxon signed-rank test is tabulated in Table 1.

Table 1: Performance result

Performance	Test Statistics	p-values
T1 and T2	9436.5	0.8808
T2 and WCT1	11078	0.0082
T2 and WCT2	10726	0.0136
T2 and WCT3	8412.5	0.7949
WCT1 and WCT2	4361	0.8079
WCT2 and WCT3	2177	0.0060

Considering the obtained results, the performance of T1 and T2, T2 and HCT3, and HCT1 and HCT2, give p-values of 0.8808, 0.7949, and 0.8079 respectively which the values are greater than $\alpha = 0.05$. Thus, we fail to reject the null hypotheses. This implies that there is insufficient evidence to conclude a significant difference between the performance of T1 and T2, T2 and HCT3, and HCT1 and HCT2. Based on these findings, we conclude that there is no statistically significant difference between T1 and T2, T2 and HCT3, and HCT1 and HCT2 performances at $\alpha = 0.05$ significance level. Besides, the performance of T2 and HCT1, T2 and HCT2, and HCT2 and HCT3, give p-values of 0.0082, 0.0136 and 0.0060 respectively which the values are less than $\alpha = 0.05$. Thus, the null hypotheses are rejected. This implies that there is sufficient evidence to conclude a significant difference between the performance of T2 and HCT1, T2 and HCT2, and HCT2 and HCT3. Based on these findings, we conclude that there is a statistically significant difference between T2 and HCT1, T2 and HCT2, and HCT2 and HCT3 performances at $\alpha = 0.05$ significance level.

B. Implications for Classroom Practice

The findings of this study have important implications for classroom practice. The incorporation of hebdomadal challenge tests as a pedagogical tool can enhance learning outcomes by promoting active student engagement, continuous learning, and reinforcing key concepts. Educators can leverage regular assessments that encourage critical thinking and problem-solving skills to create a more comprehensive and meaningful learning experience for their students. By integrating challenge tests aligned with lecture topics, educators can foster deeper understanding and retention of the subject matter.

C. Limitations of the Study

The study faced a limitation in terms of the response rate from the students. With HCT not being compulsory for all students, only 57% of the total 373 students participated in the study. This limited response rate may introduce potential biases and affect the generalizability of the findings. As the HCT was conducted during tutorial sessions, students who had missed the corresponding lecture classes might not have had the necessary knowledge or understanding to perform well in the HCT. The absence of lecture content could have adversely affected their performance on the challenges. The study acknowledged that students' performance on the HCT could be influenced by their prior knowledge. Due to differences in individual background knowledge or preparation, some students may have performed better or worse across the HCT. This variability in prior knowledge could introduce confounding factors and affect the interpretation of the results.

IV. CONCLUSION

Educators can incorporate regular HCT aligned with lecture topics to promote active learning, reinforce key concepts, and assess students' understanding. These tests can be administered using digital pedagogy platforms such as Microsoft Forms or other suitable assessment tools. The assessment data collected from HCT can provide valuable insights into individual student performance and areas of improvement. Educators can use this data to tailor their instruction and provide targeted support to students based on their specific needs within the semester.

HCT can serve as formative assessments that provide ongoing feedback to students and educators. This feedback can help identify gaps in knowledge and guide instructional decisions for improved learning outcomes. Incorporating HCT as a pedagogical tool can enhance students' engagement and motivation. The diverse student population with varying admission qualifications and prior knowledge of fundamental mathematics skills highlights the need for academic support programmes. Institutions can design targeted interventions and resources to address specific learning gaps and support students in their academic journey.

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