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ASIAN CENTRE FOR RESEARCH ON UNIVERSITY LEARNING AND TEACHING

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# Disseminating Effective Use of Mapping Techniques in Integral Calculus

Nor Hazizah Julaihi
Voon Li Li
Tang Howe Eng
*Universiti Teknologi MARA Sarawak*
*E-mail address: norhazizah@sarawak.uitm.edu.my*

ABSTRACT

*Integral Calculus has always been an issue to first year Engineering students in their Calculus courses in higher learning institutions. This paper studied mapping techniques in learning Integral Calculus. Fifty-three randomly selected first year Engineering respondents were asked to sit for a pre-test, then exposed to a treatment and finally sat for a post-test. The findings showed that there was a significantly higher mean of post-test scores as compared to the mean of pre-test scores after the application of Integral Maps in their learning. The findings indicated that the mapping techniques had a positive effect on the respondents. The respondents were fascinated with the applied bright colours in the maps. They were also fast in working out solutions as they exploited the layering design of the maps. All of the respondents would use or recommend the maps to their friends. The findings indicate that mapping techniques have potential for applications in the teaching and learning of Integral Calculus.*

***Keywords:*** *integral calculus, mapping techniques, effectiveness, techniques of integration*

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## INTRODUCTION

Integral Calculus has always been an issue to a substantial number of first year Engineering students. According to Tang et al. (2008), this issue started with the identification of the correct integration techniques out of many different techniques. This is further compounded by students' poor understanding of Integral Calculus due to lack of prior knowledge. As postulated by Yudariah and Roselainy (2001), students who do not have a solid foundation of Basic Calculus from secondary schools struggle to learn the new materials in the first year of Calculus courses in higher learning institutions. They easily lose their confidence and are overwhelmed when they attempt to solve Calculus word problems.

Salleh and Zakaria (2011) emphasise that the existing gap of Mathematics knowledge is identified as a major contributor to the decline in students' performance in Integral Calculus at the university level. This gap is due to the deterioration of Mathematics performance at secondary schools and the mismatch of teaching and learning culture between secondary schools and university. As traditional methods of teaching Mathematics have been found to be ineffective due to poor performance in certain topics of Mathematics, an innovative change needs to be implemented.

This paper proposed a Calculus procedural learning method through the application of mapping techniques, which provides an alternative way for learners to learn Integral Calculus. The mapping techniques are used because their visualization effects and the benefits of inter-knowledge correlation through procedural learning provide a rich learning experience in a simple and systematic manner for students with different abilities. As stated by Noss and Baki (1998), a lifelong and purposeful Mathematics learning can be attained only by applying both procedural and conceptual knowledge.

Three mapping techniques, i.e. mind maps, concept maps and knowledge maps in learning Integral Calculus among higher learning institutions students were initially integrated and investigated. Likewise, the Engineering students' understanding and their feedback on these techniques were also examined.

Specifically, the objectives of this paper were:

1. To compare the respondents' mean scores of achievement before and after using the mapping techniques in the learning of Integral Calculus, and

2. To investigate the respondents' perceived opinions on the use of mapping techniques in the learning of Integral Calculus.

## LITERATURE REVIEW

Educators and researchers have been studying various alternative teaching and learning approaches to minimise Engineering students' difficulties in learning Calculus and Mathematics. The advancement of computerised-based technology has seen this technology incorporated into the teaching of Mathematics across various levels of studies. Lancaster (2004) introduced a graphing calculator to his secondary school students where great success was reported as those students learned trigonometry and iteration using the calculator. Similarly, at the university level, research found that students showed enthusiasm in thinking critically as they strived to work out possible solutions to Mathematics problems in a laboratory course that integrated the handheld technology in their Mathematics education (Rosihan & Kor, 2004). Saadia (2010), meanwhile, utilized Maple software to teach selected Calculus topics with success among his Architecture students. However, he cautioned against total dependency on such programme and voiced out that students must master necessary theories, which would remain as fundamental to Mathematics knowledge. The National Council of Teachers of Mathematics (2000) has also made comparable remarks on the use of technology in Mathematics education in which they mentioned that the technology should only be used to cultivate understandings and insights and not to replace fundamental knowledge (cited in Saadia, 2010). Hence, there is a need to search, expand and develop novel techniques of Calculus learning such as mapping techniques in an era that emphasises on independence and meaningful learning as well as creativity and critical thinking.

In recent years, mind-mapping techniques have progressively been used in the area of education. Among the fields that have acknowledged the benefits are Accounting, Science and Mathematics (Chin & Norhayati, 2010; Akinoglu & Yasar, 2007; Pehkonen, 1997). Chin and Norhayati (2010) noted an increment in Accountancy students' test scores as a result of student-centered mind-mapping and this resembled the earlier findings of Akinoglu and Yasar (2007) on mind mapping and students' elevated academic achievement as well as their positive attitudes towards Science. Pehkonen (1997) also views mind-mapping as a great advantage to Mathematics students as Mathematical tasks engage both left and right hemispheres of the human brain; the left brain deduces analytically and arithmetically, and the right brain is more towards geometrical deduction.

As early as in the 1960s, Tony Buzan alerted the academic world on the idea of mind-mapping. Buzan strongly believes that one can better remember and reproduce information with the use of mind-mapping technique as the technique uses both sides of the brain (Buzan, 1976). This mental ability is made possible as the human brain is prone to capture information through visual images, i.e. colours, pictures and words more effectively as compared to the jotting of lengthy notes (Buzan, 1993). Such visualization also enables Mathematics students to create coherent procedures to solve Calculus problems (Rohani, 2010). Fortunately, an interesting, systematic and meaningful way of learning which fosters creativity is among the many benefits of mind-mapping techniques in Mathematics education as described by Brinkmann (2003). It is revealed that the topic on triangles can be learnt creatively with the aid of mind maps, which are built to resemble the structure of a tree (Figure 1).

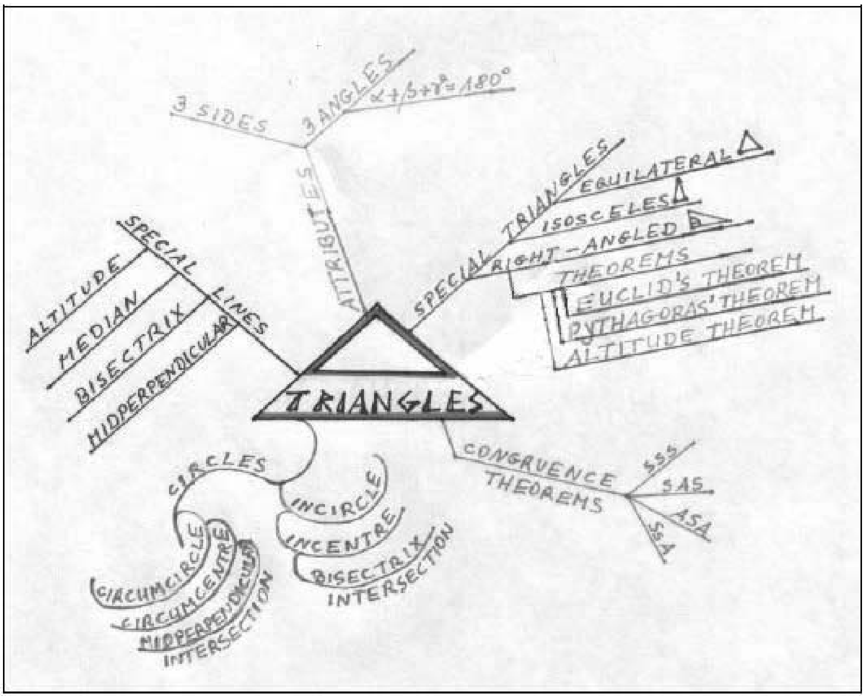



**Figure 1: Example of Mind Mapping on the Topic of Triangles**

Concept mapping which is another type of visual representation among concepts can be non-hierarchical (Harnisch et al., 1994) or hierarchical (Novak & Cañas, 2008). In concept mapping, the concepts are circled or boxed whilst the relationships among concepts are connected along the linking lines. An illustration is Brinkmann's (2003) demonstration on the use of concept map on the topic of linear equations, which trains students to think and organize knowledge into correct structures for insightful learning (Figure 2).

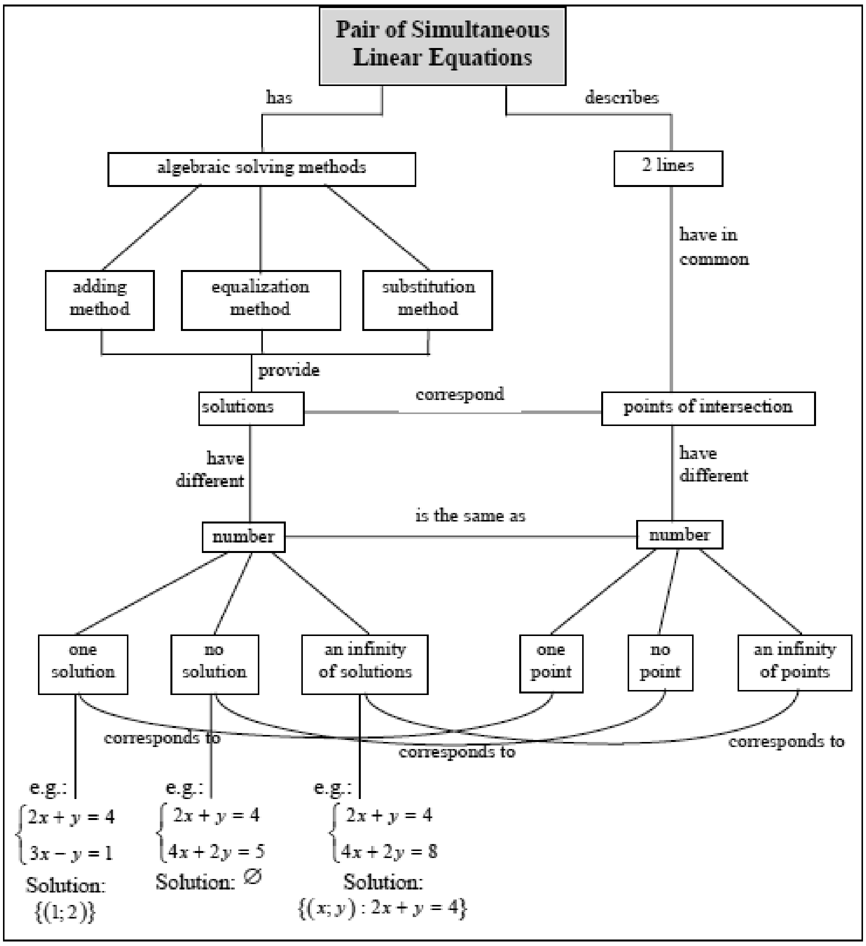



**Figure 2: Example of Concept Mapping on the Topic of Linear Equations**

Ausubel's learning theory states that the human brain assimilates new information based on current existing knowledge for meaningful learning. In fact, it is the basis of concept mapping which was introduced by Novak (Ausubel et al., 1986). Consequently, Williams (1998) discovered that concept mapping can be used as a tool to capture Mathematics students' understanding on functions beyond traditional text book learning. According to Flores (2009), when concept mapping is utilized in teaching Mathematics students, these students develop new ways of thinking and skills that assist them in the problem-solving process. As both students and teacher discuss and analyse Mathematical concepts which are implicit in nature, they create an environment of meaningful and active learning.

Nevertheless, confusion is one of the limitations of mind-mapping and sometimes, it also applies in oncept mapping. Mathematics students need to know in-depth the conceptual contexts in order to perform concept mapping. Knowing that this concept mapping represents knowledge (Ausubel et al., 1986), Brinkmann (2003) has merged both mind and concept mappings to produce knowledge mapping. When he used the mapping techniques to build structures in Mathematics, he noticed his Mathematics students were giving exemplified problem solutions. According to Sofronas et al. (2010), sixty-one per cent of his respondents viewed the ability to perform the integration techniques as vital in the understanding of Integral Calculus. With the use of computer and calculator technology, Orton (1983) states that many students do not have a real understanding of integration techniques. Students are rarely exposed to knowledge mapping despite its potential as a new way of teaching and learning Mathematics. This study initiates an attempt to develop mapping techniques as a novel way for university students to learn integration techniques.

## METHODOLOGY

This study employed an experimental design in which a randomly selected sample of Engineering respondents were initially asked to sit for a pre-test then exposed to a treatment and finally sat for a post-test after four months. This treatment consisted of the application of mapping techniques through the use of Integral Maps in solving integration problems. The Integral Maps use a specific mapping technique to help the respondents to identify the appropriate techniques of integration for solving a multitude of integral problems through unique and simple procedures.

There are many confounding factors which are threats to the validity of an experimental design. These factors include maturation, the effect of history and instrumentation. In this study, a gap of four months for conducting pre- and post- tests can serve to control the maturation of the respondents. Besides, all of the respondents experienced the same treatment in this study, thus the effect of history can be minimized. Besides, the effect of instrumentation can be controlled because the same pre- and post- tests were used in this study.

## Respondents

In this study, the respondents comprised fifty-three Engineering students from a public university in Sarawak. The cluster random sampling technique was used to select these respondents. The cluster chosen was the course code cluster of MAT235 (Calculus II for Engineers). The MAT235 students were from three Diploma Engineering programmes, i.e. Diploma in Electrical Engineering, Diploma in Civil Engineering and Diploma in Chemical Engineering.

Table 1 shows the demographic variables. The respondents consisted of thirty-five male and eighteen female students. Out of these male students, fourteen respondents were selected from Civil Engineering, ten respondents from Electrical Engineering and eleven respondents from Chemical Engineering. Meanwhile, thirteen female respondents were selected from Civil Engineering, two respondents were from Electrical Engineering and three respondents were from Chemical Engineering. Twenty-two respondents were in Semester 3, twenty-seven respondents were in Semester 4, and two respondents were in Semester 5. There was one respondent in Semester 6 and also one in Semester 7. Overall, the respondents from Diploma in Chemical Engineering were from the later semester as compared to the other programmes where the majority of respondents were in the earlier semester.

**Table 1: Respondents' Profile**

| Variables \ Programme | | Diploma in Civil Engineering | Diploma in Electrical Engineering | Diploma in Chemical Engineering | Total |
|---|---|---|---|---|---|
| Gender | Male | 14 | 10 | 11 | 35 |
| | Female | 13 | 2 | 3 | 18 |
| Semester | 3 | 14 | 8 | 0 | 22 |
| | 4 | 10 | 3 | 14 | 27 |
| | 5 | 2 | 0 | 0 | 2 |
| | 6 | 1 | 0 | 0 | 1 |
| | 7 | 0 | 1 | 0 | 1 |

## Instruments

The instruments in this study consisted of the pre- and post- tests (Appendix 1 and Appendix 2) which aimed to elicit the Engineering respondents' usage of Integral Maps. The pre- and post- tests applied the same set of questions for testing. The application of same set of testing helped to control the effect of instrumentation, in which changes in the measuring instrument may produce changes in the obtained measurements.

The pre- and post tests were divided into demographic profile, Part A and Part B sections. The demographic profile covered the respondents' programmes of studies, the course codes taken, the semester they were enrolled in, gender and group. The information of respondents' demographic profile was used in the t-test analysis and analysis of variance to compare if there was any significant difference in the mean test across different demographic profile. Part A required the respondents to indicate correct technique(s) in solving the given integrals. The questions for Part B were taken from previous examination questions; hence, they were considered as valid and reliable.

Respondents were asked to answer Part A and Part B of the test based on Integral Maps. In Part A, respondents were asked to indicate the type of bridging map and the correct technique(s) in solving the given questions by referring to the techniques of integrations in Integral Maps. In Part B, respondents were requested to solve three integral problems by showing all the steps and to indicate precisely the name of the maps used in the solution. Respondents may refer to the given examples for guidance.

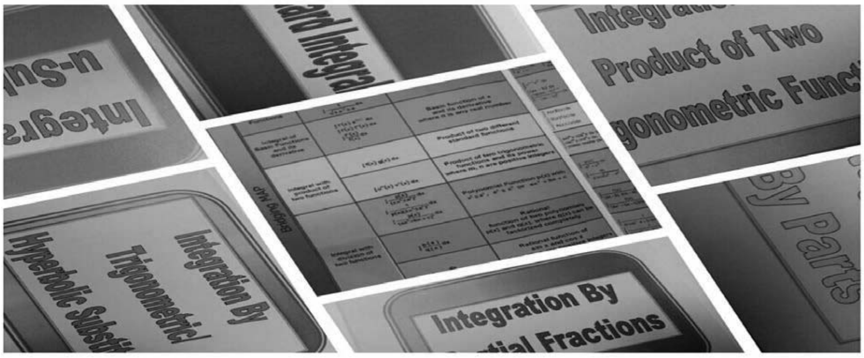
A questionnaire was also given to the respondents after the post-test. The questionnaire consisted of three sections: Section A (Respondent's Profile), Section B (Evaluation on Integral Maps) and Section C (Feedback). In Section B, the respondents were asked to evaluate Integral Maps using the 5-Likert Scale from "1" (strongly disagree) to "5" (strongly agree). The questions for Section B were adapted from MicroSIFT (1982): Evaluator's Guide For Microcomputer-Based Instructional Packages. Section C consisted of open-ended questions whereby the respondents were asked to give their opinions regarding the strengths and weaknesses of Integral Maps. Besides, they were also asked to give suggestions on the usage of Integral Maps.

## Data Collection Procedures

The Engineering respondents were given a pre-test in the early part of January 2011 as they already had basic knowledge of Integral Calculus. Then, throughout the semester, the researchers taught the respondents Integral Calculus with the aid of Integral Maps. The respondents were exposed to these maps for four months. Finally, at the end of April 2011, the respondents were asked to sit for their post-test, which was similar to the pre-test. The questionnaire was administered to the respondents after the post-test.

## Integral Maps, the Interface

The main map used in this study was known as the Bridging Roadmap. This map was extremely useful to explore integration problems. It assisted a user to identify the most suitable map for relevant integration techniques; hence, it helped to bridge conceptual knowledge to procedural learning (Figure 3).



| General Form | Form of Integral | Function in the Integral | MORE FORM OF INTEGRAL | EXAMPLE | Technique |
|---|---|---|---|---|---|
| Integral of Basic Functions | $\int f(x)dx$<br>$\int \frac{1}{a^2 \pm x^2}dx$<br>$\int \frac{1}{\sqrt{\pm x^2 \pm a}}dx$ | Basic function of x | | | Standard Integral |
| Integral of Basic Functions and its derivative | $\int f'(x)e^{f(x)}dx$<br>$\int f'(x)f^n(x)dx$<br>$\int \frac{f'(x)}{f(x)}dx$ | Basic function of x and its derivative where n is any real number | | | Integration by u-Substitution |
| Integral with product of two functions | $\int f(x)g(x)dx$ | Product of two different standard functions | | | Integration by Parts |
| | $\int u^m(x)v^n(x)dx$ | Product of two trigonometric functions and its power where m, n are positive integers | | | Integration of Product of Two Trigonometric Functions |
| | $\int \frac{p(x)}{(\pm x^2 \pm a^2)^n}dx$<br>$\int \frac{1}{p(x)(\pm x^2 \pm a^2)^n}dx$<br>$\int \frac{p(x)}{(ax^2+bx+c)^n}dx$ | Polynomial Function p(x) with $x^2 \pm a^2$, $a^2 \pm x^2$ or $ax^2+bx+c$ | | | Integration by Trigonometric / Hyperbolic Substitution |
| Integral with division of two functions | $\int \frac{p(x)}{q(x)}dx$ | Rational function of two polynomials p(x) and q(x), where q(x) can be factorized completely | | | Integration by Partial Fractions |
| | $\int \frac{dx}{u^m(x)+v^n(x)}$ | Rational function of sin x and cos x where m, n are positive integers | | | Integration of Rational Functions of sin x and cos x |

**Figure 3: The Bridging Roadmap**

To emphasise how simple Integral Maps were, these maps were divided into two layers (Figure 4). The first layer was the core layer of the maps, which contained all the important knowledge whilst the second layer of the maps provided extra information. In each map, user was given an option to open the second layer. In cases where the user needed more detailed explanation on a related concept, he or she should proceed to open the second layer for more information.

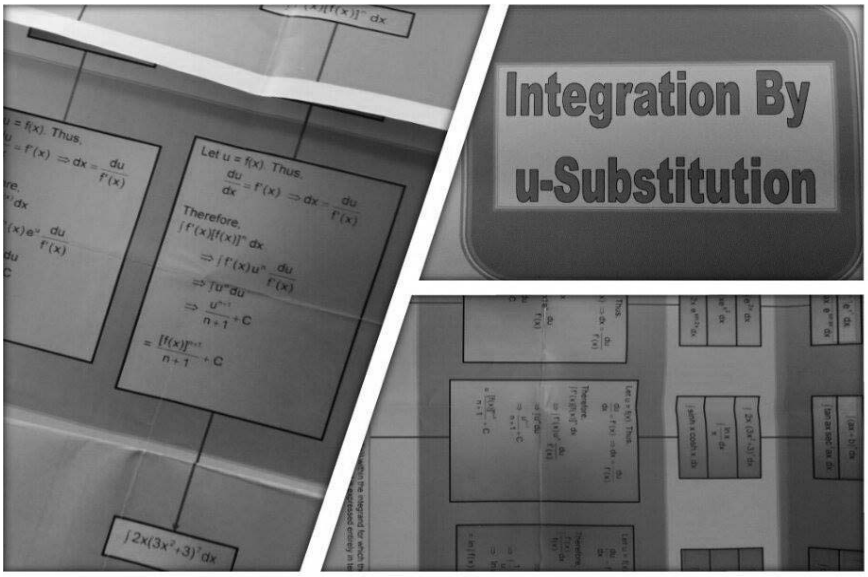



**Figure 4: Map with Two Layers**

This study used a total of seven maps consisting of maps that contained various integration techniques, i.e. integration by standard formula, integration by u-substitution, integration by parts (Figure 5), integration of product of two trigonometric functions, integration by trigonometric/ hyperbolic substitution, integration by partial fractions and integration of rational functions of sin x and cos x.

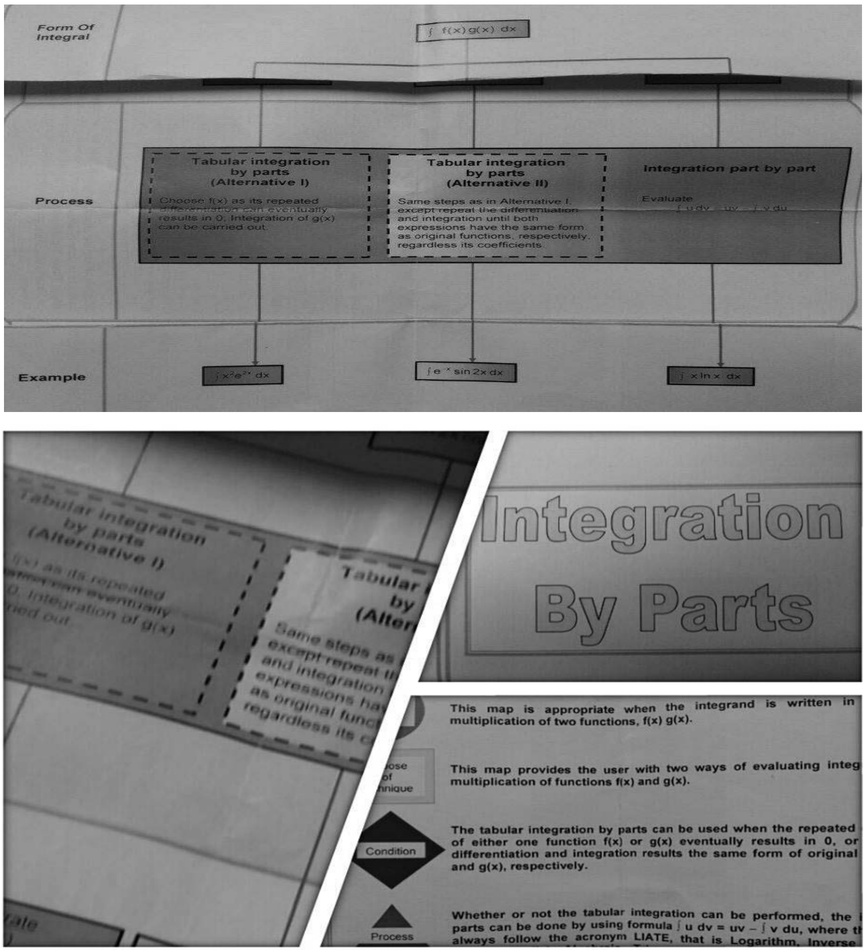



**Figure 5: The Integration by Parts Map**

These Integral Maps also consisted of prior knowledge that was useful for specific reference when using the maps. At the same time, more potential ideas for future learning could be explored together with the glossary of terms (Figure 6).

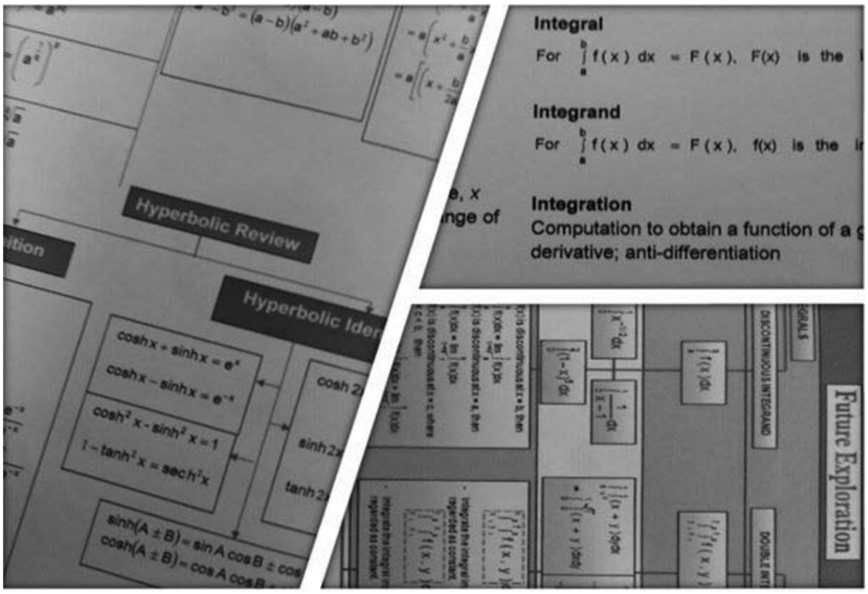



**Figure 6: Prior Knowledge, Future Exploration and Glossary**

The following example gives an idea on the use of the mapping technique in the learning of integral calculus.

Consider the problem, $\int \frac{3x^2}{1+4x^3}\,dx$. On the main interface which was the *Bridging Roadmap*, the student would be guided to make decision on the best technique of integration to solve the problem by identifying the general form and the symbolic form of the integral which could be confirmed by some examples. The phrases such as “general form”, “form of integral”, “function in the integral” and “more form of integral” used in the Bridging Roadmap represented a focus question or primary concept that must be answered. A few examples were included at the end of the concepts to aid the decision making process. When the student decided that the most appropriate map was Integration by u-Substitution since $\int \frac{3x^2}{1+4x^3}\,dx$ fits into the $\int \frac{f'(x)}{f(x)}\,dx$ form, he or she might want to read briefly the purpose, condition and process of the map. If the student was not confident to work out the solutions, then the Integration by u-Substitution map would be opened. Its core layer consisted of phrases such as 'form of integral', 'more form of integral', 'process' and 'example'. Here, the structural knowledge behind every sub-concept was outlined hierarchically using linking lines from top to bottom to show relationships between the ideas. By analyzing all the possibilities in the core layer, the student would get to choose the correct form, which eventually led them to the correct process and example types. The assistance provided in the core layer was usually sufficient for students to work out the solution independently, but if a student felt that he or she needed more guidance, then the second layer can be opened for a more detailed explanation and the step-by-step solution of some examples could be referred to.

## Data Analysis Procedures

The pre- and post-tests were marked based on a validated marking scheme. The validated marking scheme was taken from the final examinations for three courses: MAT235 (October 2008), MAT235 (April 2007) and MAT199 (October 2009) in a public university. The total marks for both tests of each Engineering respondent were recorded accordingly. The scale of measurement used in the pre- and post-tests was ratio whereby the respondents' score in each question and also the total scores of all the questions were calculated for further data analysis.

Descriptive statistics were used to analyse their demographic profiles. The mean value, frequency and standard deviation were calculated by using the Statistical Package for Social Sciences (SPSS) version 14. Further, inferential statistics were also used to make deductions based on the sampling data. Normality test and homogeneity test of variances were carried out to check on the assumptions of parametric tests, i.e. t-test and analysis of variance (ANOVA). Whilst these assumptions were not violated, the paired samples of t-test would be used to analyse whether there was any significant difference between the mean scores of pre- and post- tests. On top of that, the independent samples of t-test was utilised to analyse if there was any significant difference in the post-test scores between both male and female respondents. ANOVA was also used to analyse if there was any significant difference in both pre- and post- tests scores of respondents for these Diploma programmes. Qualitative analysis was carried out to analyze the respondents' comments and suggestions on the usage of Integral Maps.

## RESULTS AND DISCUSSION

This section reports the results of the pre- and post- tests, and the perceived opinions from the respondents obtained from the questionnaires.

### Pre- and Post- tests

To determine the effective use of the mapping techniques in solving integrals, an analysis of Engineering respondents' mean scores of pre- and post- tests was carried out. Table 2 shows the tests of normality for both scores. The data for pre-test did not fit the normal distribution; on the contrary, the data for the post-test fit the normal distribution (Sig.>0.05). As the sample size was large, paired samples t-test was used to determine if there was any significant difference between the mean scores of pre- and post- tests of the respondents.

**Table 2: Tests of Normality for Pre- and Post- tests Scores**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Pre-test | .130 | 53 | .026 | .937 | 53 | .008 |
| Post-test | .088 | 53 | .200(*) | .977 | 53 | .401 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

Table 3 shows the analysis of the paired samples t-test with regard to the mean scores of pre-test and post-test. The analysis indicated that there was a significant difference between the mean scores of both pre- and post- tests of the respondents (Sig.<0.05). The application of Integral Maps to the respondents' learning of Integral Calculus significantly increased the mean scores of pre-test from 47.06 marks to the mean scores of post-test, 57.53 marks notably.

**Table 3: Paired Sample t-test**

| Test | N | Mean | SD | t-value | df | p-value |
|---|---|---|---|---|---|---|
| Pre-Test | 53 | 47.06 | 19.615 | -3.739 | 52 | 0.000 |
| Post-Test | 53 | 57.53 | 22.440 | | | |
| Pre-Test–Post-Test | 53 | -10.472 | 20.388 | | | |

* Pre-Test Maximum Scores = 94 ; Post-Test Maximum Scores = 100

The results obtained from both pre- and post- tests indicated that the application of the Integral Maps in the learning of Integral Calculus showed some positive impact to the Engineering respondents' performance. This significant difference increase in the respondents' achievement showed that the respondents were able to perform the appropriate integration technique and procedures correctly. One possible explanation was that the built-in mapping techniques used in the Integral Maps helped the respondents to split complicated concepts into smaller sub-concepts to realize all the possible relationships that properly comprehend the entire Mathematical procedures.

The results are also in line with past research. Flores (2009) in his research found there were statistically significant differences with a confidence level of 99% in the measurement of numerical reasoning, abstract reasoning and spatial relationships for the experimental group before and after when concept maps were used for a Calculus course. This showed that the students attained meaningful learning, with the implicit use of concept mapping. Similarly, Awofala (2011) also found that students' achievements were significantly improved by the use of concept mapping strategy.

## Pre- and Post- tests Analysis on Gender

Table 4 shows the normality tests for both mean scores of pre- and post- tests on gender. The mean scores of both pre- and post- tests for the male respondents were slightly higher than the mean scores for the female respondents.

**Table 4: Tests of Normality for Pre- and Post- tests Scores on Gender**

| | Gender | N | Mean | SD | Kolmogorov-Smirnov(a) Statistic | df | Sig. | Shapiro-Wilk Statistic | df | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|
| Pre-test | male | 35 | 48.14 | 20.968 | .131 | 35 | .136 | .935 | 35 | .041 |
| | female | 18 | 44.94 | 17.041 | .129 | 18 | .200(*) | .921 | 18 | .132 |
| Post-test | male | 35 | 57.80 | 25.331 | .135 | 35 | .105 | .949 | 35 | .105 |
| | female | 18 | 57.00 | 16.018 | .130 | 18 | .200(*) | .977 | 18 | .916 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

Since the data fitted the normal distribution (Sig.>0.05), the independent t-test sample was used to determine if there was any significant difference in both mean scores of pre- and post- tests between male and female respondents. Table 5 shows the analysis of the independent t-test sample. The results indicated that there was no equal variance and no significant difference in the mean scores of pre- and post- tests between the male and female respondents (Sig.>0.05). This scenario implies that both male and female respondents performed equally in their tests.

**Table 5: Independent t-test Sample for Pre- and Post- tests on Gender**

| | | Levene's Test for Equality of Variances F | Sig. | t-test for Equality of Means t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Pre-test | Equal variances assumed | 1.315 | .257 | .558 | 51 | .579 |
| | Equal variances not assumed | | | .597 | 41.269 | .554 |
| Post-test | Equal variances assumed | 6.373 | .015 | .122 | 51 | .904 |
| | Equal variances not assumed | | | .140 | 48.628 | .889 |

Although the male and the female respondents performed equally in their pre- and post- tests, the mean scores of post-test, on the other hand, was slightly higher than the mean scores of pre-test for the male and female respondents. This is consistent with the findings of Bello and Abimbola (1997) which have shown that gender did not significantly influence respondents' concept-mapping ability and their achievements.

## Pre- and Post- tests Analysis Across Programmes of Study

Table 6 shows the descriptive statistics of pre- and post- tests scores for the different Engineering programmes. The results of pre-test showed that the respondents from Chemical Engineering scored the highest mean (62.29) followed by the respondents from Civil Engineering (41.70) and Electrical Engineering (41.33). As for the post-test, the respondents from Chemical Engineering scored the highest mean (75.93) followed by the respondents from Electrical Engineering (54.50) and Civil Engineering (49.33). The analysis across the programmes showed that the Chemical Engineering respondents scored the highest mean in both pre- (62.29) and post- (75.93) tests.

**Table 6: Descriptive Statistics of Pre- and Post- tests Scores Across Programmes of Study**

| | Programme | N | Mean | SD |
|---|---|---|---|---|
| Pre-test | Chemical | 14 | 62.29 | 18.743 |
| | Electrical | 12 | 41.33 | 13.996 |
| | Civil | 27 | 41.70 | 18.472 |
| | Total | 53 | 47.06 | 19.615 |
| Post- test | Chemical | 14 | 75.93 | 19.613 |
| | Electrical | 12 | 54.50 | 16.139 |
| | Civil | 27 | 49.33 | 21.173 |
| | Total | 53 | 57.53 | 22.440 |

Table 7 shows the tests of normality for pre- and post- tests scores across the programmes of study. For the mean scores of pre-test, the data from the Civil Engineering did not fit the normal distribution as compared to others. As for the post-test, the data from the Chemical Engineering did not fit the normal distribution; the rest of the data, on the contrary, fitted the normal distribution.

**Table 7: Tests of Normality for Pre- and Post- tests Scores Across Programmes of Study**

| | Programme | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| Pre-test | Chemical | .113 | 14 | .200(*) | .978 | 14 | .960 |
| | Electrical | .113 | 12 | .200(*) | .969 | 12 | .901 |
| | Civil | .230 | 27 | .001 | .825 | 27 | .000 |
| Post-test | Chemical | .231 | 14 | .041 | .904 | 14 | .128 |
| | Electrical | .179 | 12 | .200(*) | .890 | 12 | .119 |
| | Civil | .106 | 27 | .200(*) | .971 | 27 | .632 |

* This is a lower bound of the true significance.
A Lilliefors Significance Correction

Table 8 shows the homogeneity test of variances for both pre- and post- tests scores. From the table, there was an equal variance in the pre- and post- tests scores across the Diploma of Engineering programmes (Sig.>0.05). As the assumptions of the homogeneity test of variances were not violated for the pre- and post- tests scores, an analysis of variance was carried out to determine if there was any significant difference across these programmes.

**Table 8: Test of Homogeneity of Variances for Pre- and Post- tests Scores**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Pre-test | .437 | 2 | 50 | .648 |
| Post-test | .635 | 2 | 50 | .534 |

Table 9 shows the analysis of variance across the Engineering programmes of Diploma studies. The results indicated that there was a significant difference in both pre- and post- tests scores across these programmes ($p<0.05$).

**Table 9: ANOVA across Three Programmes of Study**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Pre-test | Between Groups | 4413.677 | 2 | 2206.838 | 7.076 | .002 |
| | Within Groups | 15593.153 | 50 | 311.863 | | |
| | Total | 20006.830 | 52 | | | |
| Post-test | Between Groups | 6663.279 | 2 | 3331.639 | 8.533 | .001 |
| | Within Groups | 19521.929 | 50 | 390.439 | | |
| | Total | 26185.208 | 52 | | | |

Table 10 shows the multiple comparisons across the Engineering programmes of Diploma studies for both pre- and post- tests. The Tukey HSD Test stated which group had differences. There was a significant difference in the test scores between Chemical Engineering and Electrical Engineering respondents in the pre-test as well as in the post-test. There was also difference between Chemical Engineering and Civil Engineering respondents.

**Table 10: Multiple Comparisons across Three Programmes of Study**

| Dependent Variable | (I) Programme | (J) Programme | Mean Difference (I-J) | Std. Error | Sig. |
|---|---|---|---|---|---|
| Pre-test | Chemical | Electrical | 20.952(*) | 6.947 | .011 |
| | | Civil | 20.582(*) | 5.816 | .002 |
| | Electrical | Chemical | -20.952(*) | 6.947 | .011 |
| | | Civil | -.370 | 6.127 | .998 |
| | Civil | Chemical | -20.582(*) | 5.816 | .002 |
| | | Electrical | .370 | 6.127 | .998 |
| Post-test | Chemical | Electrical | 21.429(*) | 7.773 | .022 |
| | | Civil | 26.595(*) | 6.508 | .000 |
| | Electrical | Chemical | -21.429(*) | 7.773 | .022 |
| | | Civil | 5.167 | 6.855 | .733 |
| | Civil | Chemical | -26.595(*) | 6.508 | .000 |
| | | Electrical | -5.167 | 6.855 | .733 |

* *The mean difference is significant at the .05 level.*

As for the multiple comparison of pre-test across the Engineering programmes of Diploma studies, the Chemical Engineering respondents (mean of 62.29) outperformed the Electrical Engineering respondents (mean of 41.33) and the Civil Engineering respondents (mean of 41.70). In addition, for the multiple comparison of post-test across the Engineering programmes, the Chemical Engineering respondents (mean of 75.93) also outperformed both Electrical Engineering (mean of 54.50) and Civil Engineering respondents (mean of 49.33).

The results indicated that the respondents from the Chemical Engineering significantly outperformed the Engineering respondents from the other two programmes in both pre- and post- tests. This could be partly due to the reason that Chemical Engineering respondents were from a later semester as compared to the other programmes where the majority of respondents were from an earlier semester.

### Respondents' Perceived views on the Integral Maps

This section reports the findings on overall perceived views from the respondents after using the Integral Maps. More precisely, it discusses the survey findings associated with the strengths and weaknesses of Integral Maps, and the respondents' views and opinions of the maps.

### Strengths and weaknesses of Integral Maps

The findings shows the respondents claimed that these maps were useful, helpful, systematic and user-friendly. However, they also commented that these maps were a little confusing and the examples given were not sufficient. This was in line with Brinkmann's (2003) view that confusion was one of the constraints for both mind and concept mappings.

Nevertheless, the majority of the respondents actually provided positive feedback on their usage of Integral Maps. Below are a few examples of the encouraging comments made by the respondents on the sentiment "useful and helpful". Five respondents explained:

*"From the map, I can identify which method to use for certain equations."*
*"Very good way to determine the technique used to solve the integration problem. I used this map and it helps me much."*
*"I like the way map been made. Using map really help me to answer the question."*
*"The maps help me to understand what method to use for any question."*
*"Very useful that helps us to find the answer faster."*

When asked about the design of the Integral Maps, four respondents viewed it as "systematic and user friendly". The comments shared by these respondents are as follows:

*"The maps are very systematic."*
*"The maps are easily to understand because have examples we can refer to."*
*"The maps is properly manage and able to guide user efficiently."*
*"I can stimulate fasten than other source. Quite an easy*

*understanding example works and procedure of executing any work."*

The qualitative findings also revealed that eight respondents wanted more examples while using the Integral Maps to assist their learning process. Below are examples of the comments given by three respondents on the sentiment "need more examples with solutions".

*"This map is very good for the students like us to study or revise on the chapter of integration. I think this map can be upgrade. On my suggestion, the way to improve this map quality or grade of this are add more example on every sub-topic and show the best solution that make students easy to remember."*
*"Good, but need more examples so that consumers will be able to use it fully."*
*"Not all type of equations included in the examples"*

The Integral Maps can be made simpler to facilitate the Engineering students' learning, especially in remedial level so that they can easily master these various integration techniques. From the findings, most respondents preferred to work in less overloaded interface, less complicated and less complex environment. They also favoured direct, easy-handling and simple human-computer interaction. Below are the examples of respondents' comments on the sentiment "bit confusing and complicated". Six respondents commented:

*"It is kind of confusing a bit initially. Anyway after a while, it is quite helpful."*
*"Useful but a bit confusing."*
*"Good maps but a little tiny bit confusing."*
*"Take time to understand on how to use the map properly."*
*"The table takes time to get used to. Too much information in one page. Can get very confusing for those who are weak."*

## Usage of Integral Maps

Table 11 shows the respondents' views on the usage of the Integral Maps. The results indicated that 41.5 per cent of the respondents would highly recommend the maps, 37.7 per cent of them would recommend the maps with little change whilst 20.8 per cent of them would recommend the maps only if certain changes were made. None of the respondents chose the last statement, "I would not use and recommend this map". This clearly showed that the respondents were very positive on the use of Integral Maps in assisting them to learn Calculus.

**Table 11: Comments on the Usage of Integral Maps**

| Comment | Frequency | Percentage (%) |
|---|---|---|
| I would use and highly recommend this map. | 22 | 41.5 |
| I would use and recommend this map with little change. | 20 | 37.7 |
| I would use and recommend this map only if certain changes were made. | 11 | 20.8 |
| I would not use and recommend this map. | 0 | 0.0 |

## Correlation between post-test scores and respondents' comments

Referring to Table 12, there was a significant positive correlation between the post-test and the ratings of the maps (Sig.<0.05, r=0.359). This illustrates that the respondents with the higher post-test score tend to rate the use of the Integral Maps more positively.

**Table 12: Correlations between Post-test scores and Comments**

| | | Post-test | Comment |
|---|---|---|---|
| Post-test | Pearson Correlation | 1 | .359(**) |
| | Sig. (2-tailed) | | .008 |
| | N | 53 | 53 |
| Comment | Pearson Correlation | .359(**) | 1 |
| | Sig. (2-tailed) | .008 | |
| | N | 53 | 53 |

** Correlation is significant at the 0.01 level (2-tailed).

## Analysis on respondents' suggestions for Integral Maps improvement

The respondents suggested recommendations to improve the Integral Maps. These recommendations included "more examples and solutions can be added", "more interesting and colourful features can be considered", "more helpful guidelines to be provided" and finally, "a one-page map rather than folded maps in many pages may be better".

Five respondents suggested that more examples and solutions were needed to understand the Calculus. Ideally, these examples, methods even solutions may be provided for a specific type of problem. The easier method to solve questions was highly favoured. Some of the comments by these five respondents were:

*"show the example of question and method to solve the question",*
*"can be more understandable if have more examples for one type of problems",*
*"need more examples and other easier ways to solve the question",*
*"put some examples and their solutions", and*
*"put more other methods and formula that used in Mathematics".*

The other five respondents, on the contrary, mentioned that the Integral Maps can be made more colourful and interesting to improve the readability of the maps and effective memorization of formulae. In addition, the bright colours can attract users' attention effortlessly. They commented:

*"make it more interesting",*
*"make it colorful and interesting to read",*
*"make it colorful so we can remember the formula more",*
*"add more color to make this map interesting", and*
*"more color and sign given can attract me".*

Notably, one respondent suggested that the Integral Maps should be displayed in one-page rather than the existing one which displayed many folded maps with many pages. He stated, "No need to make a folded note. Better in one page".

Another respondent also suggested that more clear instructions on using the maps should be added to guide them to use the maps more effectively. The respondent states, "For the first time, the map is quite confusing without guidance and instruction on how to use it".

Overall, the findings indicated how useful the maps were to the respondents.

## CONCLUSION AND RECOMMENDATION

The various difficulties and challenges faced by Engineering students in identifying suitable techniques and strategies to solve integral problems was the sole motivation for the development of Integral Maps. This study set out to determine how the maps affected the respondents' performance and to gather their perspectives on mapping techniques. The use of mapping techniques showed a positive effect on their achievements. Regardless of gender, the respondents demonstrated their learning abilities and accuracies in identifying and solving the integral problems after being exposed to the maps. The respondents also seemed to be fascinated with the use of bright colours. They worked out the solutions as they practically interacted with the layering design of the maps. Although they may have expressed confusion as it may be their first exposure or attempt to understand the techniques, none of them, however, would not use or recommend the maps to their friends.

The mapping techniques are thus very appealing to the Engineering respondents. The techniques have a practical potential to be adapted into their classroom lectures and tutorials as part of the teaching and learning pedagogy. These techniques can be used as handy resources for students to learn integration techniques at ease. However, it should be noted that the study only examined the effectiveness of mapping techniques from a few Engineering clusters in an institution where the respondents' exposures to the maps were brief, i.e. only four months. It is recommended that further research needs to be done to establish whether the maps are useful and effective to other academic programmes such as Science-based programmes besides increasing the duration of treatment between pre- and post- tests.

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# APPENDICES

## PRE-TEST

VENUE: .................... TIME : ...................... DATE : .........................

**Instruction: Please fill in all the details.**

**Name** :........................................ **Programme** :........................................

**Student ID** :........................................ **Part** :........................................

**Gender** :........................................ **CGPA** :........................................

**Course Code** :........................................ **Group** :........................................

**********************************************************************************

**PART A**

Given the following techniques of integrations:

A. Integration at Sight (by Standard Formula)
B. Integration By u-Substitution
C. Integration By Parts
D. Integration By Partial Fractions
E. Integration By Trigonometric Substitution
F. Integration of Products of Trigonometric Functions

By referring to the **above techniques**, indicate the correct technique(s) in solving the following integrals:
e.g.

| Integral | Technique(s) |
|---|---|
| $\int \tan^2 2x dx$ | B and A |

| No. | Integrals | Technique(s) |
|---|---|---|
| 1 | $\int e^{\cos x} \sin x dx$ | |
| 2 | $\int e^{3x} \sin x dx$ | |
| 3 | $\int \frac{x^2}{x^3-4} dx$ | |
| 4 | $\int \frac{x+1}{x^2-3x+2} dx$ | |
| 5 | $\int \frac{\ln x}{\sqrt{x}} dx$ | |
| 6 | $\int \frac{1}{\sqrt{25-x^2}} dx$ | |

*(Source: Engineering Mathematics (6th Edition) by K.A. Stroud (2007))*

**PART B**

Solve the following integrals. Please indicate the technique(s) used in the solution and show all the steps.
e.g.

Find $\int \cos 5x \cos 3x dx$.

**SOLUTION:**

Step 1: The integral consists of **Products of Two Trigonometric Functions**.
To solve, apply the formula:

$$2\cos A\cos B = \cos(A+B) + \cos(A-B).$$
$$\Rightarrow 2\cos 5x\cos 3x = \cos(5x+3x) + \cos(5x-3x)$$
$$\Rightarrow = \cos 8x + \cos 2x$$
$$\Rightarrow \cos 5x\cos 3x = \frac{1}{2}[\cos 8x + \cos 2x]$$
$$\therefore \int \cos 5x \cos 3x dx = \frac{1}{2}\int[\cos 8x + \cos 2x]dx$$

Step 2: Solve the integral using the **Integration At Sight**.
(i.e. using Standard Formula).

$$\int \cos 5x \cos 3x dx = \frac{1}{2}\int[\cos 8x + \cos 2x]dx$$
$$= \frac{1}{2}\left[\frac{\sin 8x}{8} + \frac{\sin 2x}{2}\right] + C$$
$$= \frac{1}{16}\sin 8x + \frac{1}{4}\sin 2x + C$$

**Questions:**

1. $\int \frac{x}{2}\sec^2 2x dx$
2. $\int \ln(x^2+4) dx$
3. $\int \frac{3}{x^2\sqrt{x^2-16}} dx$

*(Source: UiTM Final Examinations ;*
*MAT235(October 2008), MAT235(April 2007), MAT199(October 2009))*

**Appendix 1. The Pre-Test**

## POST-TEST

VENUE: .................. TIME : ...................... DATE : ..........................

**Instruction: Please fill in all the details.**

Name : ................................ Programme : ....................................

Student ID : ............................. Part : ....................................

Gender : ................................ CGPA : ....................................

Course Code : ............................ Group : ....................................

******************************************************************************************

### PART A

Given the following types of bridging map:

I. $\int p(x)^{q(x)}\,dx$

II. $\int p(x)\,q(x)\,dx$

III. $\int \frac{p(x)}{q(x)}\,dx$

Given the following techniques of integrations:

A. Integration By Standard Integral
B. Integration By u-Substitution
C. Integration By Parts
D. Integration By Partial Fractions
E. Integration By Trigonometric Substitution
F. Integration of Products of Trigonometric Functions

By referring to the **above**, indicate the correct type of map and the suitable technique(s) in solving the following integrals:

e.g.

| Integral | Type of Bridging Map | Technique(s) |
|---|---|---|
| $\int \tan^2 2x dx$ | I | A and B |

| No. | Integrals | Type of Bridging Map | Technique(s) |
|---|---|---|---|
| 1 | $\int e^{\cos x} \sin x dx$ | | |
| 2 | $\int e^{3x} \sin x dx$ | | |
| 3 | $\int \frac{x^2}{x^3-4} dx$ | | |
| 4 | $\int \frac{x+1}{x^2-3x+2} dx$ | | |
| 5 | $\int \frac{\ln x}{\sqrt{x}} dx$ | | |
| 6 | $\int \frac{1}{\sqrt{25-x^2}} dx$ | | |

*(Source: Engineering Mathematics (6th Edition) by K.A. Stroud (2007))*

### PART B

Solve the following integrals by using the relevant map(s). Please indicate the map(s) used in the solution and show all the steps.

e.g.

Find $\int \cos 5x \cos 3x dx$ .

**SOLUTION (USING THE MAPS):**

Step 1: Refer to e-**Bridging Map**, The correct type is $\int p(x)\,q(x)\,dx$

Step 2: In the e-Products of Trigonometric Functions Map, use $\int \cos ax \cos bx dx$

Step 3: Apply $2\cos A\cos B = \cos(A+B) + \cos(A-B)$.

⇨ $2\cos 5x\cos 3x = \cos(5x+3x) + \cos(5x-3x)$

⇨ $= \cos 8x + \cos 2x$

⇨ $\cos 5x\cos 3x = \frac{1}{2}[\cos 8x + \cos 2x]$

$\therefore \int \cos 5x \cos 3x dx = \frac{1}{2}\int [\cos 8x + \cos 2x]dx$

Step 4: Refer to the example and solution given in the map, get idea to solve.

Step 5: By referring to the e-**Standard Integral Map**, solve the integral.

$\int \cos 5x \cos 3x dx$

$= \frac{1}{2}\int [\cos 8x + \cos 2x]dx$

$= \frac{1}{2}\left[\frac{\sin 8x}{8} + \frac{\sin 2x}{2}\right] + C$

$= \frac{1}{16}\sin 8x + \frac{1}{4}\sin 2x + C$

*or (in simpler way)*

Refer to **e-Bridging Map** and e-**Products of Trigonometric Functions Map**:

Apply $2\cos A\cos B = \cos(A+B) + \cos(A-B)$

⇨ $2\cos 5x\cos 3x = \cos(5x+3x) + \cos(5x-3x)$

⇨ $= \cos 8x + \cos 2x$

⇨ $\cos 5x\cos 3x = \frac{1}{2}[\cos 8x + \cos 2x]$

$\therefore \int \cos 5x \cos 3x dx = \frac{1}{2}\int [\cos 8x + \cos 2x]dx$

Refer to e-**Standard Integral Map**:

$\int \cos 5x \cos 3x dx = \frac{1}{2}\int [\cos 8x + \cos 2x]dx$

$= \frac{1}{2}\left[\frac{\sin 8x}{8} + \frac{\sin 2x}{2}\right] + C$

$= \frac{1}{16}\sin 8x + \frac{1}{4}\sin 2x + C$

**Questions:**

1. $\int \frac{x}{2} \sec^2 2x dx$

2. $\int \ln(x^2+4)dx$

3. $\int \frac{3}{x^2\sqrt{x^2-16}} dx$

*(Source: UiTM Final Examinations ;
MAT235(October 2008), MAT235(April 2007), MAT199(October 2009))*

**Appendix 2. The Post-Test**

## QUESTIONNAIRE

****************************************************************

***Section A (Respondent's Profile)***
**Instruction: Please fill in.**

Gender : ..............................

Age : ..............................

Race : ..............................

Place of Birth : ..............................

Education Qualification : ..............................

Program : ..............................

Part : ..............................

CGPA : ..............................

***Section B (Evaluation on Integral Map)***
**Instruction: This is an evaluation on the use of Integral Map. Read each sentence and circle your choice. There is no right or wrong answers. Your answers will be kept secret. Remember to answe all the items.**

1-Strongly Disagree 2-Disagree 3-Neutral 4-Agree 5-Strongly Agree

CONTENT

1. The content of the Integral Map is easy to understand. 1 2 3 4 5
2. The content of the Integral Map is accurate. 1 2 3 4 5
3. The content of the Integral Map is useful to solve integration question. 1 2 3 4 5
4. The content of the Integral Map guides me to identify the correct integration technique quickly. 1 2 3 4 5
5. The content of the Integral Map is not confusing. 1 2 3 4 5
6. The content of the Bridging Integral Map gives a big picture for deeper understanding where relationships between Integral Maps are shown clearly. 1 2 3 4 5

INSTRUCTIONAL

7. The level of difficulty of the Integral Map is appropriate for me. 1 2 3 4 5
8. The graphics / colour are used for appropriate instructional reasons. 1 2 3 4 5
9. The use of the Integral Map is motivational. 1 2 3 4 5
10. The Integral Map effectively stimulates my creativity. 1 2 3 4 5
11. The presentation of the Integral Map is clear and logical. 1 2 3 4 5
12. I can control the rate and sequence of using the Integral Map accordingly. 1 2 3 4 5
13. The purpose of the Integral Map is well defined. 1 2 3 4 5
14. The Integral Map achieves its defined purpose. 1 2 3 4 5
15. The instruction is integrated with my previous experiences. 1 2 3 4 5
16. The learning can be generalized to an appropriate range of situations. 1 2 3 4 5

TECHNICAL

17. The Integral Map is reliable in normal use. 1 2 3 4 5
18. The information displays are effective. 1 2 3 4 5
19. I can easily and independently use the Integral Map. 1 2 3 4 5
20. The Integral Map is comprehensive in term of its support for you. 1 2 3 4 5
21. The Integral Map is effective in term of clear, readable and attractive printed text. 1 2 3 4 5
22. The Integral Map is effective in term of readable and appropriate diagrams. 1 2 3 4 5

*(Adapted from MicroSIFT (1982). Evaluator's Guide For Microcomputer-Based Instructional Packages. Oregon: International Council for Computers in Education.)*

***Section C (Feedback)***
**Instruction: Please respond to the following items.**

**Strengths of the Integral Map:**

..............................................................................................

..............................................................................................

..............................................................................................

**Weaknesses of the Integral Map:**

..............................................................................................

..............................................................................................

..............................................................................................

**Other Comments / Suggestions (for better improvement):**

..............................................................................................

..............................................................................................

..............................................................................................

***Section D (Recommendation)***
**Instruction: Please tick (√) the best choice.**

| | | |
|---|---|---|
| 1. | I would use and highly recommend Integral Map. | |
| 2. | I would use and recommend Integral Map with little or no change. | |
| 3. | I would use and recommend Integral Map only if certain changes were made. | |
| 4. | I would not use and recommend Integral Map. | |

**Appendix 3. The Questionnaire**