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THE EFFECTIVENESS OF e-INTEGRAL MAP IN SOLVING INTEGRAL CALCULUS PROBLEMS

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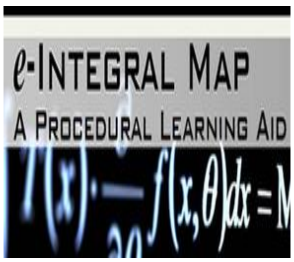
Graphical abstract



Abstract

The existing gap of mathematics knowledge was identified as the major contributor to the decline in the students' performance on the Integral Calculus at the university level. This phenomenon has led to university students' difficulties in identifying the correct integration techniques and developing understanding on applications of the Integral Calculus. This study aims to analyse the effectiveness of e-INTEGRAL MAP in the learning of Integral Calculus among engineering students of advanced Calculus class. A total of 118 diploma engineering students were involved in an experimental design research to study on the usage and effectiveness of e-INTEGRAL MAP. Study was performed on 65 students in control group and 53 students in treatment group, using the pre-test and post-test experimental design methodology where the effectiveness of the maps was measured through their performance scores. Findings indicate that both control and treatment groups showed significant differences in post-test scores during the two months study. The majority of e-INTEGRAL MAP users found the maps very useful, helpful, easy to understand and user-friendly because it was systematically designed. In conclusion, e-INTEGRAL MAP significantly improved the students' performance and understanding on the topic of Integral Calculus as compared to the conventional text-book learning.

Keywords: Effectiveness, e-INTEGRAL MAP, integral calculus, integration techniques, experimental design

Abstrak

Jurang yang sedia ada dalam pengetahuan matematik telah dikenal pasti sebagai penyumbang utama kepada penurunan prestasi pelajar dalam topik Kalkulus Pengamiran di peringkat universiti. Fenomena ini telah memberikan kesukaran kepada pelajar universiti di dalam mengenal pasti teknik pengamiran yang betul dan memahami aplikasi kalkulus pengamiran. Kajian ini dibuat bertujuan untuk menganalisis keberkesanan e-INTEGRAL MAP dikalangan pelajar kejuruteraan dalam mempelajari topik Kalkulus Pengamiran. Seramai 118 orang pelajar diploma kejuruteraan telah dipilih telah terlibat di dalam kajian reka bentuk eksperimen mengenai penggunaan dan keberkesanan e-INTEGRAL MAP. Kajian telah dilakukan ke atas 65 orang pelajar dalam kumpulan kawalan dan 53 pelajar dalam kumpulan rawatan, menggunakan ujian pra dan pos metodologi reka bentuk eksperimen di mana keberkesanan e-INTEGRAL MAP boleh diukur melalui skor prestasi mereka. Hasil kajian mendapati bahawa kesemua kumpulan kawalan dan rawatan menunjukkan perbezaan yang signifikan dalam skor ujian pos bagi tempoh dua bulan kajian. Majoriti pengguna mendapati e-INTEGRAL MAP sangat berguna, sangat membantu, mudah difahami dan mesra pengguna kerana rekaannya yang sistematik. Kesimpulannya, e-INTEGRAL MAP secara signifikan boleh meningkatkan prestasi dan pemahaman pelajar terhadap topik Kalkulus Pengamiran.

Kata kunci: Keberkesanan, e-INTEGRAL MAP, kalkulus pengamiran, teknik pengamiran, reka bentuk eksperimen

1.0 INTRODUCTION

The existing gap of mathematics knowledge was identified as the major contributor to the decline in the students' performance on the Integral Calculus at the university level. Salleh and Zakaria (2011) emphasized that the gap was due to the deterioration of mathematics performance at secondary schools and the mismatch of teaching and learning culture between secondary schools and university [1].

Integral Calculus has always been an issue to many first year engineering students. According to Tang *et al.* (2008), this issue started when students failed to identify and use the correct integration techniques out of many different techniques available in Calculus. This was further compounded by the students' poor understanding in their prior knowledge [2].

Tang *et al.* (2010) reported that students always encounter problems in solving derivatives and integrals because they are confused with the various integration and differentiation techniques due to lack of initiative to do exercises. Unable to think critically in complicated situation or procedures has made them ignorant to the conceptual aspects of the subject and relied more on memorizing the rules and procedures [3].

This phenomenon has led to university students' difficulties in identifying the correct integration techniques and developing understanding on applications of the Integral Calculus. The world of today demands for the application of Calculus as a powerful tool to understand, analyze, apply, and solve a wide range of industries and businesses problems. Thus, a good mastery in Integral Calculus is deemed necessary for university students.

This study focused on the use of e-INTEGRAL MAP as an interactive learning tool through the application of mapping techniques, which provides an alternative way for learners to learn Integral Calculus. The mapping techniques are used because of their visualization effects and the benefits of inter-knowledge correlation through procedural learning that provide a rich learning experience for different abilities of students in a simple and systematic manner. The objective of this study is to test the effectiveness of e-INTEGRAL MAP in Integral Calculus learning.

1.1 Uses of Mapping Techniques to Support Learning

In recent years, educators from various fields such as engineering, nursing, biology, and business studies have attempted to introduce mapping techniques as contemporary method in their teaching and learning across diverse level of studies [4, 5, 6, 7] According to Kamble and Tembe (2013), about 70% of mechanical engineering students liked to use concept mapping to solve problem, while 88% of students would use concept mapping for self-study as they realized that with the help of mapping technique, they achieved better understanding on concepts and their connections [5].

As mentioned by Coffey *et al.* (2003), the usage of mapping techniques seemed to benefit the slow learners as it was believed that their abilities to understanding, inquiring, and accepting knowledge in an orderly but active manner became more natural [8]. With the implementation of concept mapping in engineering course, Kamble and Tembe (2013) reported significant students' performance in problem solving as compared to the traditional way of learning [5]. Debrenti (2015) had reported students' improvement in mathematical reasoning as the result of the use of visual representation [9].

1.2 Technological Tools in the Teaching and Learning of Integral Calculus

The advancement of computerised-based technology, has seen technology been incorporated into the teaching of mathematics across various levels of studies. Lancaster (2004) introduced graphing calculator to his secondary school students where great success was reported as those students learned trigonometry and iteration using the calculator [10]. Similarly, at the university level, Rosihan and Kor (2004) 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 [11].

Saadia (2010), meanwhile, utilized *Maple* software to teach selected Calculus topics with success among his architecture students [12]. 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. Since the types of technologies tools, delivery and teaching methods contributed to students' mathematics learning (Momin & Shaikh, 2016), 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 [13].

2.0 METHODOLOGY

This study employed the quantitative procedure to investigate the effectiveness of using e-INTEGRAL MAP for learning Integral Calculus at a higher learning institution. This study employed an experimental design in which 118 engineering students were sampled from a public university in Sarawak. These students enrolled from two engineering programmes of diploma studies, i.e. Diploma in Electrical Engineering (EE111) and Diploma in Civil Engineering (EC110). The cluster random sampling technique was then used to select these respondents. The cluster chosen was the course code cluster of MAT235 (Calculus II for Engineers). All MAT235 students from Diploma in Electrical Engineering and Diploma in Civil Engineering for Semester June – October 2013 were thus used as the respondents.

Further, the 118 respondents were randomly assigned to treatment and control groups. Random assignment resulted in 53 students for treatment group while 65 students were selected in control group. The treatment group comprised of three classes, namely EE1113B, EE1113C and EC1103B. On the other hand, the control group also comprised of three classes, namely EE1113A, EE1113R and EC1103A. Both groups were of mixed abilities with regard to intelligence.

The treatment group was initially asked to sit for a pre-test before being exposed to a treatment, and eventually sat for a post-test after two months. This treatment consisted of the application of mapping techniques through the usage of e-INTEGRAL MAP.

The treatment group used e-INTEGRAL MAP in their two hours class. They learned on how to identify the appropriate techniques of integration for solving a multitude of integral problems through e-INTEGRAL MAP. They were given an access to the website and practised e-INTEGRAL MAP for two months with reference to the given questions.

On the other hand, the control group was asked to sit for a pre-test on the same day as the treatment group. This group was not exposed to any treatment and was taught using the usual notes-pen-paper style of teaching and learning. After two months, the control group sat for a post-test on the same day as the treatment group.

The instruments in this study consisted of the pre- and post- tests. They were used to elicit the respondents' usage of e-INTEGRAL MAP. Both the treatment and control groups sat for the pre- and post- tests at the same interval of time. The pre- and post- tests utilized the same set of questions for the testing. The pre- and post- tests were divided into demographic profiles, Part A and Part B sections. The questions for Part A and Part B were taken from a well-known Calculus reference book and also from previous examination questions, hence considered as valid and reliable.

The data collected were analyzed by using IBM SPSS Statistics version 20. Descriptive statistics were generated on the mean pre- and post- test scores, standard deviation, minimum and maximum scores. Analysis of Variance (ANOVA) was calculated to identify if there is any significant difference in mean pre-test scores for treatment groups as well as for control groups. Analysis of Variance (ANOVA) was also calculated to identify if there is any significant difference in mean post-test scores for treatment groups as well as for control groups. Paired samples t-test was used to identify if there is any significant difference in mean pre-test scores and mean post-test scores for treatment groups as well as for control groups.

2.1 e-INTEGRAL MAP

e-INTEGRAL MAP is critically constructed in such a way that allows learners to learn integration techniques from a 'big picture' through the connection of concepts, sub-concepts and propositions into meaningful 'wholes'. The blending of hierarchical and layered methods as its two unique formats provide users with the opportunity to make decisions in problem solving as they are led to experience varying levels of difficulty in content. Visual effects are also utilized to enhance learning and understanding. Besides providing a rich learning experience and reinforcement, it is able to cater to different level of ability for different users, which eventually encourages independence in learning. The design and inspiration of e-INTEGRAL MAP are based on the idea of concept maps, which was first developed by Novak in the 1980s.

Table 1 shows the list of contents in e-INTEGRAL MAP. The webpage consists of four main menus namely Home Content, Help Manual, Glossary and About. Home Content menu is the main interface of the e-INTEGRAL MAP comprising of six main icons such as Calculus Atlas, Prior Knowledge, Future Knowledge, List of Formulas, Bridging Map and e-INTEGRAL MAP (Figure 1). The user can freely explore e-INTEGRAL MAP as it provides user-friendly environment to the user. Besides, menus naming Home Content, Help Manual, Glossary and About also help the user to explore e-INTEGRAL MAP effectively. The main map of e-INTEGRAL MAP is known as the Bridging Map. This map is extremely useful to the user in exploring the integration problems. It assists the user to identify the most suitable map(s) for the relevant integration techniques, and hence helps in disseminating the bridging conceptual knowledge for the procedural learning (Figure 2).

To further assist the user, there are three options for the Bridging Map; naming Bridging Map Type-I, Bridging Map Type-II and Bridging Map Type-III. Bridging Map Type I caters for the form $\int p(x)^{q(x)}dx$, Bridging Map Type-II caters for the form $\int p(x)q(x)\,dx$ and Bridging Map Type-III caters for the form $\int \frac{p(x)}{q(x)}dx$.

From the Bridging Map, the user can choose to explore any of the seven maps (under icon e-INTEGRAL MAP) that contains various integration techniques, namely e-Standard Integral, e-By u-Substitution, e-By Parts, e-Rational Function of sine(x) and cosine(x), e-By Trigonometric/Hyperbolic Substitution, e-By Partial Fractions and e-Product of Two Trigonometric Functions. The specific map of e-By u-Substitution is shown in Figure 3.

The e-INTEGRAL MAP also consist of some notes on the Prior Knowledge (Figure 4) that is useful for specific reference when using the maps; at the same time, more potential ideas for the Future Learning can be explored together with Calculus Atlas and List of Formulas.

Table 1 The contents of e-INTEGRAL MAP

NUM	ICON	DESCRIPTION
I	HOME CONTENT	Consists of the main items as follows :
	Calculus Atlas	A list of the main topics in Calculus.
	Prior Knowledge	Some notes on Prior Knowledge.
	Future Knowledge	Some notes on Future Knowledge.
	List of Formulas	A list of the relevant Integral Formulas.
	Bridging Map	Consists of a list of the 3 TYPES OF INTEGRAL FORM.
	e-INTEGRAL MAPs	Consists of the set of 7 e-INTEGRAL MAPs.
II	HELP MANUAL	Description of all the seven e-integral maps. Provide guideline of using each map.
III	GLOSSARY	A list of all important mathematics terms used in the maps.
IV	ABOUT	Brief introduction to integral problem. Also contains the features and the novelty of e-

Figure 1 The main interface of e-INTEGRAL MAP

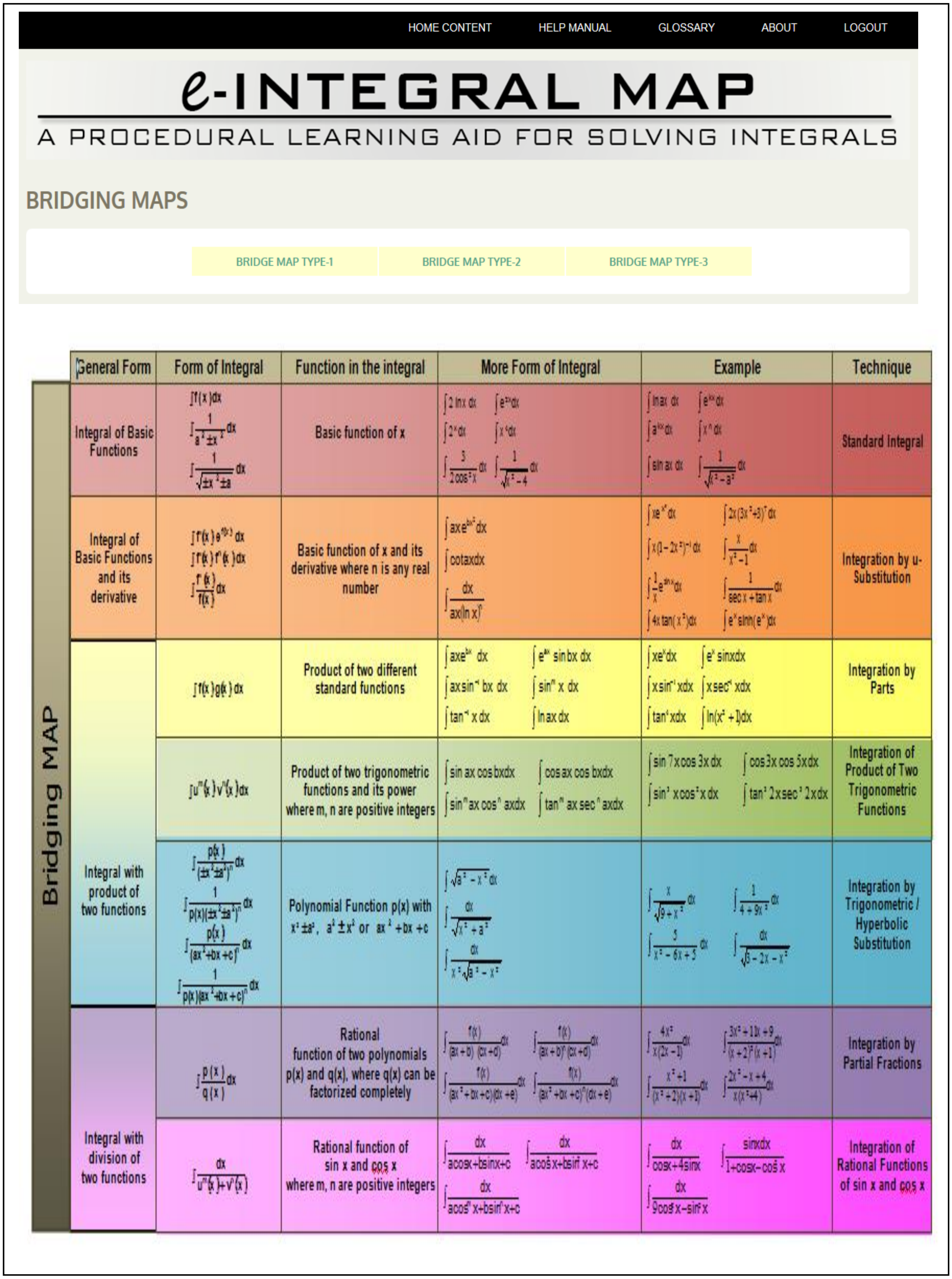


Figure 2 The bridging map of e-INTEGRAL MAP

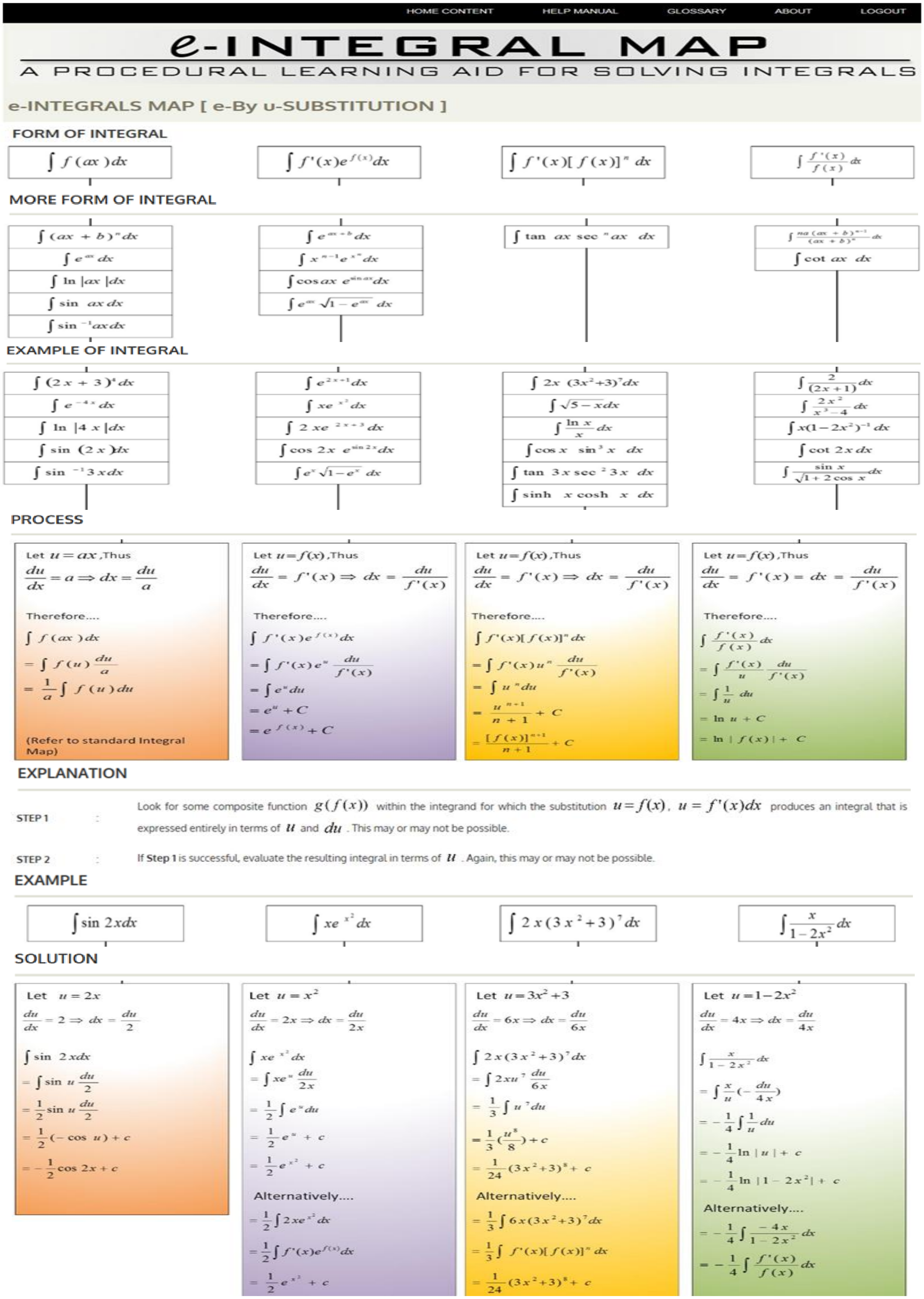


Figure 3 The e-By u-Substitution map

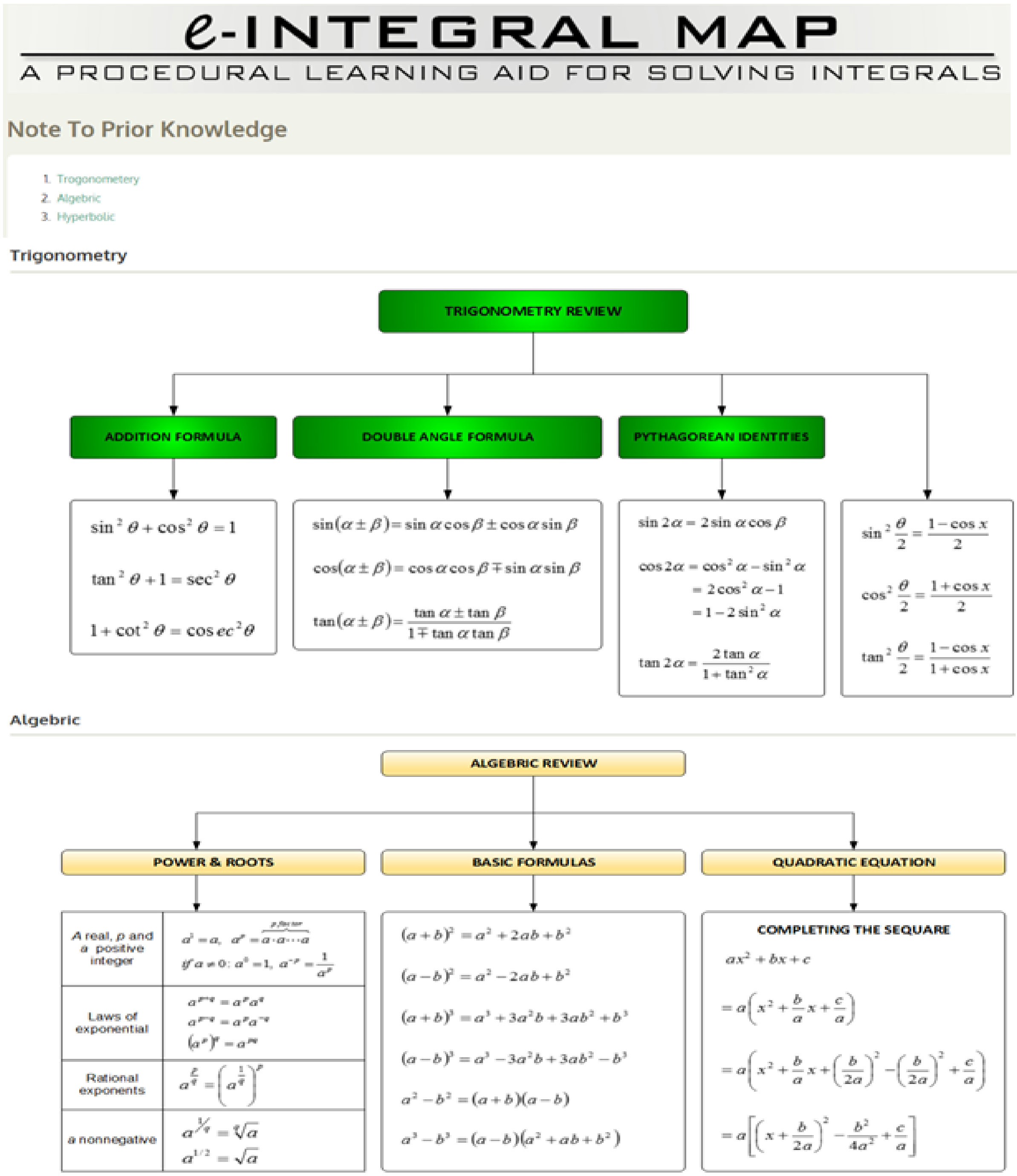


Figure 4 The Prior Knowledge of e-INTEGRAL MAP

3.0 RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics of pre-test scores across control groups. The results of pre-test showed that the respondents from EE1113A scored the highest mean (16.94) followed by the respondents from EE1113R (16.75) and EC1103A (16.36).

Table 2 Descriptive statistics of pre-test scores across control groups

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Min	Max
EE1113A	20	16.94	5.61	1.26	14.31	19.57	6.50	29.50
EE1113R	8	16.75	4.40	1.55	13.08	20.43	11.25	22.50
EC1103A	37	16.36	5.46	.90	14.54	18.18	8.00	28.50
Total	65	16.59	5.32	.66	15.27	17.90	6.50	29.50

Table 3 shows the homogeneity test of variances for pre-test scores across control groups. From the table, there was an equal variance in the pre-test scores across control groups (Sig.>0.05). As the assumptions of the homogeneity test of variances were not violated for the pre-test scores, an analysis of variance was carried out to determine if there was any significant difference across control groups.

Table 3 Test of Homogeneity of Variances for pre-test scores across control groups

Levene Statistics	df1	df2	Sig.
.168	2	62	.846

Table 4 shows the analysis of variance across control groups. The results indicated that there was no significant difference in pre-test scores across control groups (Sig.>0.05).

Table 4 ANOVA for pre-test scores across control groups

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4.608	2	2.304	0.079	.924
Within Groups	1805.552	62	29.122		
Total	1810.160	64			

As for the post-test scores across control groups (refer Table 5), the respondents from EE1113R scored the highest mean (19.00) followed by the respondents from EC1103A (15.47) and EE1113A (14.13).

Table 5 Descriptive statistics of post-test scores across control groups

					95% Confidence Interval			
	N	Mean	Std. Dev	Std. Error	Lower Bound	Upper Bound	Min	Max
EE1113A	20	14.13	3.62	.81	12.43	15.82	8.50	21.50
EE1113R	8	19.00	6.04	2.13	13.95	24.05	8.00	23.50
EC1103A	37	15.47	4.49	.74	13.98	16.97	7.00	29.75
Total	65	15.49	4.62	.57	14.35	16.64	7.00	29.75

Table 6 shows the homogeneity test of variances for post-test scores across control groups. From the table, there was an equal variance in the post-test scores across control groups (Sig.>0.05). As the assumptions of the homogeneity test of variances were not violated for the post-test scores, an analysis of variance was carried out to determine if there was any significant difference across control groups.

Table 6 Test of Homogeneity of Variances for post-test scores across control groups

Levene Statistics	df1	df2	Sig.
1.461	2	62	.240

Table 7 shows the analysis of variance for post-test scores across control groups. The results indicated that there was a significant difference in post-test scores across control groups (Sig.<0.05).

Table 7 ANOVA for post-test scores across control groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	135.836	2	67.918	3.424	.039
Within Groups	1229.660	62	19.833		
Total	1365.496	64			

Table 8 shows the multiple comparisons for post-test scores across control groups. The *Tukey HSD Test* stated the classes of control group in which differences had occurred. In the post-test, there was a significant difference in the test scores between EE1113A and EE1113R groups. The analysis across these groups showed that EE1113R scored significantly higher as compared to EE1113A in the post-test.

Table 8 Multiple comparisons for post-test scores across control groups

		Mean Dif.	Std. Error	Sig.	95% Confidence Level	
(I) group	(J) group				Lower Bound	Upper Bound
EE1113A	**EE1113R**	*-4.88	1.86	.03	-9.35	-.40
	EC1103A	-1.35	1.24	.52	-4.32	1.62
EE1113R	**EE1113A**	*4.87	1.86	.03	.40	9.35
	EC1103A	3.53	1.74	.11	-.64	7.70
EC1103A	**EE1113A**	1.35	1.24	.52	-1.62	4.32
	EE1113R	-3.53	1.74	.11	-7.70	.64

*The mean difference is significant at the 0.05 level.

Table 9 shows the descriptive statistics of pre-test scores across treatment groups. The results of pre-test scores showed that the respondents from EE1113B scored the highest mean (19.23) followed by the respondents from EC1103B (19.16) and EE1113C (17.78).

Table 9 Descriptive statistics of pre-test scores across treatment groups

					95% Confidence Interval			
	N	Mean	Std. Dev	Std. Error	Lower Bound	Upper Bound	Min	Max
EE1113B	11	19.23	2.50	.75	17.55	20.91	15.25	23.50
EE1113C	16	17.78	4.68	1.17	15.29	20.27	8.75	23.25
EC1103B	26	19.16	4.80	.94	17.22	21.10	11.00	28.00
Total	53	18.76	4.36	.60	17.56	19.96	8.75	28.00

Table 10 shows the homogeneity test of variances for pre-test scores across treatment groups. From the table, there was an equal variance in the pre-test scores across treatment groups (Sig.>0.05). As the assumptions of the homogeneity test of variances were not violated for the pre-test scores, an analysis of variance was carried out to determine if there was any significant difference across treatment groups.

Table 10 Test of Homogeneity of Variances for pre-test scores across treatment groups

Levene Statistics	df1	df2	Sig.
3.022	2	50	.058

Table 11 shows the analysis of variance for pre-test scores across treatment groups. The results indicated that there was no significant difference in pre-test scores across treatment groups (Sig.>0.05).

Table 11 ANOVA for pre-test scores across treatment groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.961	2	10.981	.567	.571
Within Groups	967.534	50	19.351		
Total	989.495	52			

Table 12 shows the descriptive statistics of post-test scores across treatment groups. The results of post-test scores showed that the respondents from EC1103B scored the highest mean (22.34) followed by the respondents from EE1113C (16.52) and EE1113B (14.27).

Table 12 Descriptive statistics of post-test scores across treatment groups

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Min	Max
EE1113B	11	14.27	4.35	1.31	11.35	17.20	9.25	22.50
EE1113C	16	16.52	6.81	1.70	12.89	20.14	8.00	27.00
EC1103B	26	22.34	6.14	1.20	19.86	24.82	11.50	29.00
Total	53	18.91	6.88	.94	17.01	20.80	8.00	29.00

Table 13 shows the homogeneity test of variances for post-test scores across treatment groups. From the table, there was an equal variance in the post-test scores across treatment groups (Sig.>0.05). As the assumptions of the homogeneity test of variances were not violated for the post-test scores, an analysis of variance was carried out to determine if there was any significant difference across treatment groups.

Table 13 Test of Homogeneity of Variances for post-test scores across treatment groups

Levene Statistics	df1	df2	Sig.
2.630	2	50	.082

Table 14 shows the analysis of variance for post-test scores across treatment groups. The results indicated that there was a significant difference in post-test scores across treatment groups (Sig.<0.05).

Table 14 ANOVA for post-test scores across treatment groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	633.545	2	316.773	8.673	.001
Within Groups	1826.108	50	36.522		
Total	2459.653	52			

Table 15 shows the multiple comparisons for post-test scores across the treatment groups. The *Tukey HSD Test* stated the classes of treatment group in which differences had occurred. In the post-test, there was a significant difference in the test scores between EE1113B and EC1103B groups. The analysis across these treatment groups showed that EC1103B scored significantly higher as compared to EE1113B in the post-test. Likewise, in the post-test, there was also a significant difference in the post-test scores between EC1103B and EE1113C groups. EC1103B scored significantly higher as compared to EE1113C.

Table 15 Multiple comparisons for post-test scores across treatment groups

(I) group	(J) group	Mean Dif.	Std. Error	Sig.	95% Confidence Level Lower Bound	95% Confidence Level Upper Bound
EE1113B	EE1113C	-2.24	2.37	.61	-7.96	3.47
	EC1103B	-8.06*	2.17	.00	-13.31	-2.81
EE1113C	EE1113B	2.24	2.37	.61	-3.47	7.96
	EC1103B	-5.82*	1.92	.01	-10.46	-1.18
EC1103B	EE1113B	8.06*	2.17	.00	2.81	13.31
	EE1113C	5.82*	1.92	.01	1.18	10.46

*The mean difference is significant at the 0.05 level.

Table 16 shows the paired samples statistics for both treatment and control groups. For the treatment groups, the mean for the post-test scores (18.91) was slightly higher as compared to mean for the pre-test scores (18.76). As for the control groups, the mean for the post-test scores (15.49) was slightly lower as compared to mean for the pre-test scores (16.58).

Table 16 Paired samples statistics for both treatment and control groups

		N	Mean	Std deviation
Treatment Groups	Pre-score	53	18.76	4.36
	Post-score	53	18.91	6.88
Control Groups	Pre-score	65	16.58	5.32
	Post-score	65	15.49	4.62

However, paired samples t-test showed that there was no significant difference between the mean scores of both pre- and post- tests for both treatment and control respondents (Sig.>0.05) as they performed equally in their pre- and post-tests. Thus, the application of e-INTEGRAL MAPs to the treatment respondents in the learning of Integral Calculus had not significantly increased the mean scores of the post-test.

4.0 CONCLUSION

With respect to the Integral Calculus learning, the findings indicated that there was a significant difference in post-test scores across control groups. For the post-test scores across control groups, EE1113R scored significantly higher as compared to EE1113A in the post-test. As for the treatment groups, the analysis of variance for the post-test scores revealed that there was a significant difference in post-test scores across treatment groups. Treatment group EC1103B scored significantly higher as compared to EE1113B in the post-test. Likewise, in the post-test, EC1103B also scored significantly higher as compared to EE1113C treatment group.

Specifically, this study aims to analyse the effectiveness of e-INTEGRAL MAP in the learning of Integral Calculus among engineering students of advanced Calculus class. Advanced Calculus course on the topic of Integral Calculus that requires various appropriate integration techniques was the subject of this research. A total of 118 diploma engineering students were involved in an experimental design research to study on the usage and effectiveness of e-INTEGRAL MAP. Study was performed on 65 students in control group and 53 students in treatment group, using the pre-test and post-test experimental design methodology over a period of two months. Pre- and post-tests were administered to both the control group and treatment group where the effectiveness of the maps was measured through their performance scores.

All the control and treatment groups showed significant difference in post-test scores during the entire two months study. The civil engineering students had improved mean scores after using e-INTEGRAL MAP. One group of electrical engineering students also showed increment in mean scores after using e-INTEGRAL MAP. There is indication that mapping techniques which stimulate dynamic, analytical and logical style to learning may benefit the lower ability learner more that the higher ability students' learning styles [8]. Nevertheless, another one group of electrical engineering students actually recorded lower mean scores after using e-INTEGRAL MAP. This group of students may have difficulty in finding information quickly from the maps for the reason that the structure of information is too complex for them [8].

The various difficulties and challenges faced by engineering students in identifying suitable techniques and strategies to solve integral problems became the sole motivation for the usage of e-INTEGRAL MAP. Lectures and tutorials were conducted in treatment group to solve Integral Calculus problems by using e-INTEGRAL MAP, while the control group was taught the same topic without using the maps. Majority of e-INTEGRAL MAP users found the maps very useful, helpful, easy to understand and user-friendly as it was systematically designed. e-INTEGRAL MAP significantly improved students' performance and understanding on the topic of Integral Calculus as compared to the conventional text-book learning.

However, the findings analysed from inferential statistics cannot be generalised because this result may indicate some unknown consequences. Future research can be carried out for a larger sample size; that is, it can include students from other programmes of studies such as chemical engineering, computer science and applied science. This research only studied a limited small sample of 118 engineering students. The method and duration for the treatment also need to be improved as it is believed that in this study, the treatment groups were not sufficiently exposed to e-INTEGRAL MAP due to limitations such as time constraint and internet networking problems. Learning Calculus by using the mapping techniques was a new thing to these students and one cannot expect them to be familiar to the knowledge presented in this technical way, and so, it needs to be practised. Despite the very minimal increment in the mean scores of treatment groups, e-INTEGRAL MAP has revolutionized the way students think and learn Integral Calculus, and its potential effectiveness to students' conceptual understanding of Integral Calculus is worth to be researched further.

For future research work, consideration should be given to investigate the variables which are not studied in this research due to inevitable constraints in time, resources, and design. Possible variables such as gender and learning style can also be investigated. In particular, it should seek to find out which of those variables will significantly correlate to students' performance on Integral Calculus when mapping techniques is used in the teaching and learning methodology.

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