The Effects of Maple Integrated Strategy on Engineering Technology Students' Understanding of Integral Calculus

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ABSTRACT
The objective of this research is to investigate the effectiveness of a learning strategy using Maple in integral calculus. This research was conducted using a quasi-experimental nonequivalent control group design. One hundred engineering technology students at a technical university were chosen at random. The effectiveness of the learning strategy was examined through three variables on two groups of these students. Data were analyzed using Hotelling's T^2 and explained by interview data. The advantages offered in Maple enable students' thinking to be amplified. Students benefit from the conceptual and procedural understanding of integral calculus. However, they need more time to improve their metacognitive awareness. The transformation of the integral calculus learning approach using Maple has the potential to overcome engineering technology students' under-preparedness. As a result, the nation's inadequacy in the related workforce may be overcome.

Keywords: Integral calculus, conceptual understanding, procedural understanding, metacognitive awareness, technology integration, Maple software

INTRODUCTION
The focus of Malaysian industries has shifted toward emphasizing research and development, thus innovating and producing high-technology products ahead of other countries (Board of Engineers Malaysia, Institution of Engineers Malaysia, & Federation of Engineering Institution of Islamic Countries, 2003). Hence, the type of workforce required has also moved from cheap labor to the highly skilled. In this sense, Malaysia has to produce enough science, technology, engineering, and mathematics (STEM) majors to meet the country's industrial needs. With this vision, the Malaysian government has urged universities to produce engineers who are competitive in the global market (Ismail & Puteh, 2008). Furthermore, in complementing engineers' work, engineering technologists are needed to help Malaysia become a more industrialized nation.

The fields of engineering and engineering technology greatly differ. Nevertheless, they are strongly associated professions. Engineering education frequently focuses on theory and conceptual design, while engineering technology education focuses on science and mathematics application aspects. Graduates of engineering programs are called engineers. Engineering technology programs, which are completed in four years, produce graduates known as technologists. Graduates who have completed any two-year engineering technology programs are called technicians (ABET, 2011). Engineers often enter the workforce as conceptual designers or researchers in developing new technologies. Instead, engineering technologists are responsible for transforming engineers' designs and ideas into practical devices and products (Mynbaev et. al., 2008). In that view, engineering technology education aims to prepare graduates for the practice of improvement and manufacturing of products to accommodate the needs of the engineering field.

In Malaysia, the engineering technology field does not compete with the conventional engineering field. Instead, it compensates the workforce produced by the engineering field to realize the country's vision. Thus, an adequate number of technologists is required to achieve the vision. This implies that an increased number of students choosing STEM majors is required. The ideal ratio between technologists to engineers needed by Malaysia to be an industrial country is 2:1 (Othman, 2010). However, the current ratio is 1:3, which has led to an 80% shortage of engineering technologists (Ali et Al., 2009; Othman, 2010). To overcome the problem, universities producing graduates in the field of engineering technology have to ensure an adequate number of graduates to cater to the country's industrial needs. The need to increase the number of students choosing STEM majors and graduate on time has led to better preparation and performance in regards to the subjects related to

STEM (LeBeau et al., 2012). One of the required subjects to successfully complete STEM majors is mathematics, particularly calculus (LeBeau et al., 2012).

However, the prevailing obstacle that inhibits students from graduating on time is poor performance in mathematics (Mynbaev et al., 2008). One possible reason why students perform poorly in this subject is because they are not well versed with the threshold concepts in this subject. One important threshold concept in mathematics for engineering technology courses is calculus. However, students entering the courses at the university were found to be underprepared on this topic. This under-preparedness has been portrayed by the remedial courses offered to bridge the gap in students' understanding (Henderson & Broadbridge, 2007; Lavicza, 2010; Selden, 2005). The university involved in this research also faces the same problem. In order to tackle the problem, the university has practiced its own designed remedial mathematics courses. Even with the measures taken, students in this university still face problems with the threshold concept of integral calculus.

The inability to get through this topic has an effect on higher mathematics and other technical subjects, as this topic serves as a prerequisite. It is important to maximize the number of students that graduate on the time scheduled because their service is needed in developing our nation. If they fail to complete their studies on time, the effect is not only their future but also the nation's growth in general. The country's economic growth depends on advances in industrial activities. The industrial activities will grow healthier when engineers and engineering technologists work together. To make this vision a reality, the number of workforce in both areas has to remain sufficient. With that in mind, suitable measures to handle the problem require proper planning. Any teaching and learning situation is a product of three elements: curriculum, pedagogy, and assessment (Osborne, 2007). Thus, in this research, to ensure students' engagement and high successful rate in the engineering technology field, a new pedagogical approach in integral calculus has been designed and implemented.

Integral calculus is one of the subtopics in calculus to be mastered by students majoring in science, technology, engineering, and mathematics (STEM) (Bryant et al., 2011; Haripersad, 2011). However, many students have difficulties in comprehending this topic (Bryant et al., 2011; Grove, 2012; Haripersad, 2011; Kashefi, Ismail, Yusof, & Rahman, 2012; Mynbaev et al., 2008; Özkan & Ünal, 2009; Salleh & Zakaria, 2012a; Yates, 2012). Furthermore, in the university involved in this research, students' learning philosophy is geared toward dependently receiving help and guidance from others during the learning process rather than independently exploring the possibilities by themselves.

Besides, students expect to receive rewards on each successful task done where they define rewards as marks. They seem not to realize the importance of conceptual understanding as a meaningful reward. This frame of mind is the result of their under-preparedness in this subject, where they previously acquired knowledge through rote learning rather than understanding (Blank, 2000). Furthermore, they will only gain confidence in solving mathematical problems if they are given the final answer to refer to. In this sense, generally, students are more concerned about the final product than the process toward solving/creating the product. Without a solid understanding of this topic, students may face difficulties in learning calculus-related application subjects during their studies (Özkan & Ünal, 2009). Under-preparedness in school calculus can affect first-year university students' understanding (Burton, 1989). To ensure a smooth transition between school mathematics with the mathematics at the university, the gap has to be closed. Thus, a careful strategy has been planned and implemented.

To succeed in mathematics, students must become fluent in the process and understand the mathematical concepts. In cultivating the culture of learning with understanding at this university, a new teaching strategy has been designed and implemented. The strategy was developed to close the gap of students' under-preparedness on this topic. This measure is important in order to maximize the number of students that graduate on time. In the first stage of the strategy development, a needs analysis has been carried out. The results indicated that students' active involvement in the learning process using hands-on activities led to meaningful learning in integral calculus. Conversely, the existing teaching practice still focuses on the teacher-centered method. A new paradigm of teaching practice focuses on student-centered needs in order to maximize students' potential. Student-centered learning requires the active involvement of students, which can be implemented based on constructivism theory (Bergsten, 2008; Dubinsky, 1991, 2001). Studies have shown that the constructivism theory is effective in a computer-technology-integrated environment (Colonna & Easley, 2011; Ward, 2003). With technology, students are flexible in adjusting their learning strategy based on their learning style (Salleh & Zakaria, 2012b).

Learning mathematics using technology yields a positive impact in terms of student understanding (Ayub, Mokhtar, Luan, & Tarmizi, 2010; Fox-Turnbull, 2012; Highfield & Goodwin, 2008; Lee, 2004; Noinang, Wiwatanapataphee, & Wu, 2008; Wiwatanapataphee, Noinang, Wu, & Nuntadilok, 2010). However, these studies have not emphasized the importance of students' learning style in developing a mathematics teaching strategy using technology. In addition, not many studies have discussed the advantages of technology on conceptual understanding, procedural understanding, and metacognitive awareness in learning integral calculus. In this research, the current teaching method has been enhanced with the integration of enhancement of technology. This teaching strategy was designed to promote students' understanding through exploring integral calculus using mathematics software, known as Maple.

The teaching strategy developed emphasizes the understanding of where the elements of conceptual understanding function as the core components. However, the importance of the procedural fluency has not been ignored. This element also was given equal weight in designing the strategy. Fluency in the process may entail certain memorization of crucial steps. Nevertheless, the combination of memorization and understanding are optimum in a continuing nature rather than in two isolation aspects (Kember, 2000). In this sense, learning commences with a surface approach, which gradually transforms into a deeper understanding through activities, class discussions, reflections, and exercises. Therefore, the enhanced teaching strategy aims to help engineering technology students to understand integral calculus by learning this topic using Maple-integrated strategies.

Explicitly, this research focuses on investigating the effectiveness of Maple-integrated learning strategies in integral calculus. The effectiveness of the strategy has been determined based on three variables, which focus on understanding and metacognitive awareness. The understanding of integral calculus has been investigated through students' conceptual and procedural understandings. The findings of this research inform mathematics educators, generally, and mathematics educators in the field of engineering technology, specifically, about a suitable strategy to teach integral calculus at the university.

METHODOLOGY

Two groups of Technical Mathematics 2 with various mathematics backgrounds, consisting of 100 students, were randomly chosen. One lecturer was appointed by management to handle the tutorial classes for these 100 students. A quasi-experimental nonequivalent control group design was employed as the main research design. The researchers randomly chose the experimental and control groups. The former group underwent integral calculus lessons using Maple software. The intervention is known as "Maple as a Learning Tool Strategy." In this strategy, both lecture and tutorial modes were practiced during the teaching and learning of integral calculus. In the lecture, the topic was taught using PowerPoint presentations. In this mode, the lecturer played an important role to teach students the lessons. However, students were encouraged to interact when lecturers consistently posed questions to them in order to trigger their thinking processes.

During the tutorial sessions, students used Maple software as a learning tool to assist in their learning process. Throughout these sessions, students were independently responsible for doing the tutorial questions in which the lecturer played a role as the facilitator. Thus, students were encouraged to collaboratively work in a group to do their tasks within the given time frame. The learning strategy was developed based on a constructivism theory, known as APOS (action, process, object, and schema), pioneered by Dubinsky. The assumption of APOS theory is as follows:

Assumption of mathematical knowledge: An individual's mathematical knowledge is his/her tendency to respond to perceived mathematical problem situations and their solutions by reflecting on them in a social context, and constructing or reconstructing mental structures to use in dealing with the situations (Dubinsky & McDonald, 2001; Maharaj, 2010; Weller, Arnon, & Dubinsky, 2011).

The activities during tutorial sessions were executed based on the ACE (activities, class discussions, and exercises) teaching cycle. In this cycle, activities were conducted with a great emphasis on reflective element. This element was highly considered because reflective activities are able to trigger students' thinking skills and, hence, develop their metacognitive awareness in learning (Salleh & Zakaria, 2012b; Vos & Graaff, 2004). In addition, the quality of reflection activities affects students' achievement (Chang & Chou, 2011). Students who are stimulated with learning awareness and act on it are inclined to learn better (Pintrich, 2002).

On the other hand, students representing the control group underwent the integral calculus lessons as usual. Similar to the experimental group, this group also practiced lectures and tutorials as the means to disseminate the information. PowerPoint presentations were also used as an aid to learning. However, the teaching approach in this group lacked the explanation about the integral calculus concepts. Instead, it highlighted the fluency of the mechanical parts, which involve the calculation processes. Students were given samples of past years' examination questions as an exposure for them to recognize patterns of questions. They were encouraged to memorize the patterns as a method to prepare them for the examination. In this group, the lecturer played an important role in explaining the methods of solving integral calculus questions, while student passively listened and copied the notes. This approach was adopted because the thinking paradigm of the lecturer involved remains geared toward the philosophy that he or she is the only knowledge expert (Zakaria & Iksan, 2007). Therefore, lecturers typically believe that learning will only take place when students are clearly told what and how they can learn. In the tutorial classes, students in the control group completed their tutorial activities manually without any mathematics software.

Instruments

In this research, the instruments used to gather the data are a set of integral calculus questions and a metacognitive awareness questionnaire. The former set of instruments was built by the researcher based on the integral calculus curriculum at the university. The latter instrument, known as metacognitive awareness inventory (MAI), was adapted from Schraw and Dennison (Schraw & Dennison, 1994). Both instruments have been scientifically piloted to ensure its reliability and validity. A group of 79 engineering technology students was chosen at random to answer the integral calculus questions. They also agreed to answer the MAI. Two constructs were investigated in both instruments. In the integral calculus test, the constructs are conceptual understanding and procedural understanding. In the MAI, the constructs are knowledge of cognition and regulation of cognition. The reliability of both domains in the instruments was investigated using Rasch model analysis. In this analysis, two reliabilities were determined: item reliability and person reliability.

The item reliability for the two constructs in the integral calculus test was measured high with 0.95 for conceptual understanding and 0.96 for procedural understanding. The person reliability for both constructs was also proven as being adequate. The indices are 0.77 for conceptual understanding and 0.86 for procedural understanding. The item reliability for the two constructs in MAI was also high (0.97 for knowledge of cognition and 0.96 for regulation of cognition). Similarly, the person reliability for both constructs was acceptably adequate, which is 0.71 and 0.87, respectively.

Data Collection

The data collection started with a pretest, which was given to ensure the homogeneity in both the experimental and control groups. It also provides the information related to students' pre-knowledge of integral calculus. Measurement of pre-knowledge is an important element in helping students to develop new meaningful ideas based on their prior knowledge (Davis, 1986). The information about integral calculus background of the students involved is important, as they had entered the university with various mathematics preparations. Consequently, the information obtained is used to design activities in learning this topic. Also, based on the information gathered, three students were selected from each group to represent three different levels of pre-knowledge on this topic. This step is crucial in identifying similarities and differences in students' understanding of these three pre-knowledge levels after the use of the software at the end of the integral lessons.

The integral calculus lessons took place in a 40 hour period, which is equivalent to four hours of face-to-face lessons and four hours of self-learning time in a five-week duration. After the intervention, a post-test was conducted to investigate the effectiveness of the Maple integration intervention approach. Three students from three different pre-knowledge levels, determined at the beginning of the lessons, were interviewed. Their interview sessions were audio and video recorded. Prior to the interview session, they were given an information sheet and a consent form to sign. All of them agreed to participate in the interview session. They also gave their agreement to all the conditions stated in the consent form.

The quantitative data were analyzed using the statistical package PASW Statistics 18. To minimize the statistical error Type 1, Hotelling's T2 multivariate test was employed. The test was applied to investigate the effectiveness of the Maple integration strategy on students' conceptual understanding, procedural understanding, and metacognitive awareness. Consequently, the independent t-tests were conducted in determining the effect of each dependent variable. The quantitative data were explained by the interview data, which was analyzed qualitatively.

RESULTS

Statistical Results

Table 1 shows the outcomes of Hotelling's T^2 and the independent t-tests for both dependent variables.

Table 1. Multivariate and univariate test results

Variables	Hotelling's T^2	*t*-test	Probability, *p*	Effect size, η^2
Maple Integrated Strategy	0.26		0.00	0.20
Conceptual Understanding		4.64	0.00	0.18
Procedural Understanding		4.42	0.00	0.17
Knowledge of Cognition		0.08	0.94	
Regulation of Cognition		0.31	0.76	

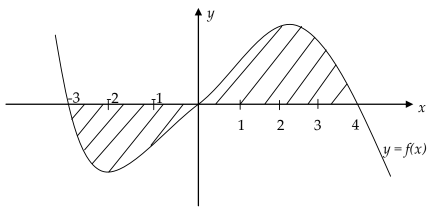
Table 1 shows that the statistical significance is supported by the large effect size in order to imply the significance effectiveness of the whole treatment. Based on the reported effect size value, the effectiveness of the whole Maple integrated strategy is considered large. Eta squared value (η^2) for the whole treatment is 0.20 > 0.14, which is equivalent to Cohen's *d* of 1.01 > 0.80. This value is considered as a large effect size value (Cohen, 1988). Further investigation, which was done using a *t*-test, shows that students in the experimental group outperformed their peers in terms of conceptual understanding and procedural understanding of integral calculus. These two dependent variables were found to largely contribute to the significant differences between those using Maple software with those using the conventional method in learning integral calculus with the η^2 value of 0.18 and 0.17, respectively (Cohen's *d* = 0.94 and 0.89). However, the results for MAI differ, where both constructs of students' metacognitive awareness in both groups were not significantly different.

Interview Data

In order to explain how the new strategy implemented has successfully improved students' understanding of integral calculus, interview sessions were conducted. In this paper, the discussion was made based on the analysis of two questions measuring students' conceptual understanding in integral calculus. The first question analyzed was Question 4 (Figure 1), which was designed to measure students' understanding in the application of a definite integral (area under the curve). In this question, students were expected to recognize and write the correct formula to evaluate the area of the shaded region.

Question 4

The following diagram shows the area between the x-axis and the function $y = f(x)$.



Write down the integral to evaluate the shaded area in the diagram.

Figure 1. Question 4 in the integral calculus test.

In this part, two application questions will be discussed. The questions are Question 4 and Question 12. Both questions were about evaluating an area between curves. In Question 4, the diagram is given to assist students to interpret the question easily.

The second question, Question 12 (Figure 2), requires the student to interpret the information given in order to correctly answer the question. In this question, students were tested on their ability to apply the definite integral properties to calculate the area. In this case, students are required to understand the difference between the upper and lower limits. Most importantly, they need to be aware that there are at least two different cases of $f(x)$ available. Finally, they need to be able to correctly write the two different area formulas.

Question 12
Given a function $f(x)$ defined on $[a, b]$. How to determine the area of the region bounded by curves $y = 0, y = f(x)$, and the lines $x = a, x = b$?

Figure 2. Question 12 in the integral calculus test.

Interview Data 1
Interview with a student from a low integral calculus pre-knowledge (EL1)
Researcher: Do you know why didn't you get any marks for Question 4?
EL1: We cannot integrate directly from -3 to 4 because there is an area below the x-axis, and there is an area above the x-axis … oh dear… I didn't have an idea to do it … I didn't have any thought … I didn't know what to write … I knew it cannot be done directly … if it is done directly … we will not get the answer.
Researcher: What kind of question do you think can be evaluated directly?
EL1: It is not like this … it is … (He paused and did not continue his sentence.)
Researcher: Let me rephrase the question, in terms of the graph, how will the graph of a function that can be integrated directly look like?
EL1: Uhhh … how to say …
Researcher: Based on the graph given, what will happen if we directly evaluate function in Question 4?
EL1: Hmmm … you take the graph directly … I think so.
Researcher: What do you mean?
EL1: Hmmm … I don't know … that's why I cannot get the answer …
EL1 flipped through the test paper and sighed
I was careless in doing a lot of questions. This one with four marks (referring to Question 12), this one maybe I forgot; that's why I lost two marks for this question.

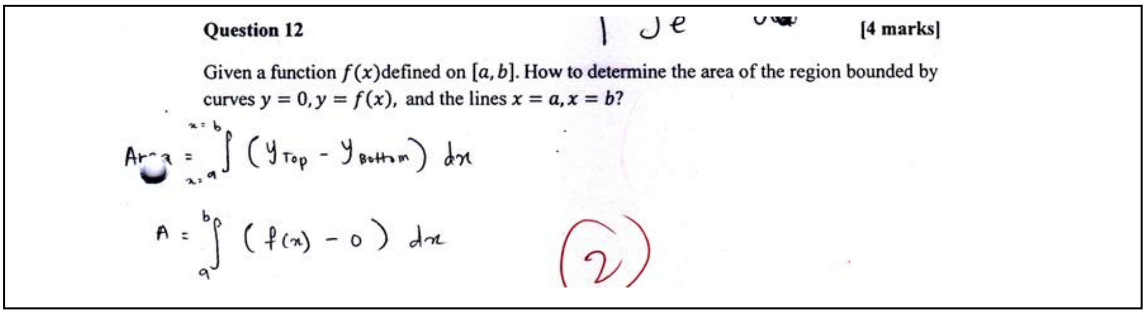

Question 12 [4 marks]
Given a function $f(x)$ defined on $[a, b]$. How to determine the area of the region bounded by curves $y = 0, y = f(x)$, and the lines $x = a, x = b$?
$\text{Area} = \int_{x=a}^{x=b} (y_{Top} - y_{Bottom})\, dx$
$A = \int_a^b (f(x) - 0)\, dx$
(2)

Figure 3: EL1's Answer to Question 12 in the Integral Calculus Test

Figure 3. EL1's answer to Question 12 in the integral calculus test.

Researcher: In Question 12, you have shown that you understand the method involved in evaluating an area. However, you only considered one case.
EL1: Sometimes the y = 0 is above the function given, but its limit remains as a and b right?
Researcher: Can you look at the Question 4 again. For the region x = 0 to x = 4, which one is the upper function?
EL1: y = f(x)
Researcher: In this case, is there any lower function?
EL1: This one, x … x-axis.
Researcher What is the equation of the x-axis?
EL1: x = 0 …
Researcher: Are you sure x = 0?
EL1: y value. y = 0.

Researcher: *Okay, actually what is the upper function in this question?*
EL1: *y = f(x)*
Researcher: *What about the lower function?*
EL1: *y = 0*
Researcher: *What about this part of the function (pointing to x = -3 to 0)*
EL1: *y upper, y = 0, y bottom y = f(x)*
Researcher: *Can you try to answer this question again?*

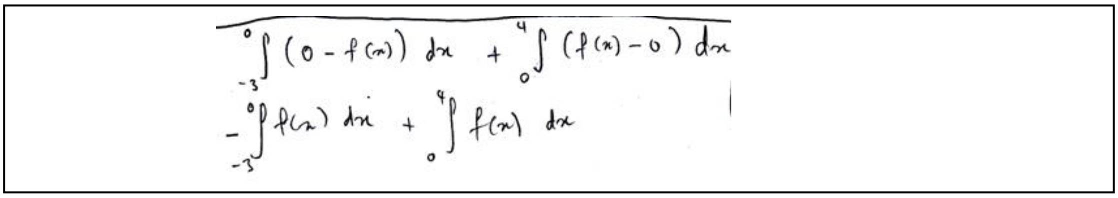


Figure 5. EL1's answer during the interview session.

EL1: *Writing line one (refer to student's test paper [Figure 4])*
Researcher: *Can you simplify?*
EL1: *Writing line two (refer to student's test paper [Figure 4])*
Researcher: *Here you go …*
EL1: *Last minute study … argh … this is the result of the last minute study …*

Interview Data 2

Interview with a student from a medium integral calculus pre-knowledge (EM1).

Researcher: *How did you find the test this morning?*

EM1: *I can do, but there are some hard questions. The area part that requires us … y 0, y = f(x). The one that provides a graph (referring to Question 4) … how to do it … usually, my lecturer gives, what, there are numbers given. And then it stated … bounded to x. Bounded to uhh … but this time, the question did not specifically give the values. The question does not provide specific functions, it only gives, it gives you = f (x), it is confusing. y = 0. Confused, and then … ok… it's okay, I just remember the basic, I just wrote the answer.*

Researcher: *Have you seen this type of question before?*

EM1: *I'm not sure … maybe I've seen this type of question before, but maybe I didn't attempt … it was difficult … One more question is number 12. I think, I saw, there are two functions, the question gives the function y = f(x), because this one 0, but it calculates what … the function, too… and then f(x) dx and then, there are two points meaning if we draw the graph, there should be an intersection point, and then I … how to say, but I remember my lecturer taught in class, there is one function above, the area is above, and area under the graph, I managed to recall the steps … uhh … and then I tried to apply the concept, and then there was a line … this one actually to find x value, right?*

Researcher: *It's given.*

EM1: *Ohh … like last time, to find x values we have to equate both… in the graph there are two functions, y = x and one more* $y = x^2$*,* $x = x^2$*, we equate and transfer, and then solve the equation … uhh … how … factorize and get the x value, and then substitute the x value in a and b.*

Researcher: *What is the objective to find x value?*

EM1: *To find the area. x is the value … the limit value I think … or … I don't know how to explain.*

Researcher: *What is the meaning of the x value?*

EM1: *Limit. The limit for finding the area. For example (drawing a graph) … I don't know how the graph looks like, but, for example (drawing a graph), but the question gives the intersection points … (solving for the intersection point). Equate, and then we transfer… wait… can we solve this (Thinking how to factorize … talking to himself…* x^2 *+ 1… x). We equate to zero. We can factorize right? We get two values … and then … they will become the limit values … limits for this graph … for example, the limits are -2 and 1. And then, we substitute in a and b.*

Researcher: *In our case, in this Question 12, what do you understand about this question? Can you explain to me?*

EM1: *The question asks us to find an area, curve, to find the area under the graph… we don't have to find the values. We need to solve based on the concepts. Based on the first step, we will get, what … step … step to find the answer.*

Researcher: *When you wrote the first answer (pointing to the first answer written), what did you actually think about? Can you explain to me?*

EM1: Uhh … I think there are two … how should I explain … (pause) … I think its graph. How did I answer? I think how the graph looks like … there is one graph below the x-axis and there is another graph above the x-axis. Therefore, if the graph is below the x-axis, the zero value minus f(x).
Researcher: Value?
EM1: What … uhh … it is this function … the one that we … and then, for the upper graph, uhh … what … f(x) minus zero, and then lastly we add.
Researcher: Are you sure that we have to add?
EM1: That's right … actually, I didn't expect my answer is correct. Because at the time I wrote the answer, it's okay, it seems … This question was actually the last question that I answered. Because I don't know… just follow … what… my heart … follow my instinct … I didn't expect my answer is correct.
Researcher: Your instinct is correct this time …
EM1: I read many times, but I still didn't know what the question wants us to find … do we have to find the limit? ... what was actually the question … because I thought the question asks us to find the intersection point or the limits … I'm very weak in the part involving area. In fact, many of us do not understand the concept … I looked … okay … how to do this because … I'm weak in math especially the word problems, I have to write again; for example, the part involving volume …

Interview Data 3
Interview with a student from a high integral calculus pre-knowledge (EH1).
Researcher: You managed to get full marks for Question 4. How did you do this question, can you explain to me?
EH1: Based on what did I learn, based on what did I remember … lower than x-axis, negative. I know why it is negative because 0 minus f(x).
Researcher: What is 0?
EH1: 0 because that line … y is zero at the x-axis.

DISCUSSION

In the interview, EL1 realized the reason behind his unsuccessful attempt in gaining any marks in Question 4. In this case, he understood well that he cannot evaluate the area from $x = -3$ to $x = 4$ directly. He knew it was the reason why he did not score any marks for this question. He has shown his understanding of the concept of evaluating an area with two regions by dictating an important point on the existence of two different regions. Also, he managed to identify that the process of evaluating an area involving two different regions is not directly doable. However, he is unable to link between the evaluations of two isolate areas with a combination of two areas or regions.

Additional questions were posed in order to further investigate the reasons why he was unable to answer Question 4, although he has shown an understanding of the concept involved. Based on the answer written on the test paper, it is obvious that EL1 understands the method of evaluating an area. He correctly wrote the definition, where he knew about evaluating an area; thus, the method involved is by subtracting the lower function from the upper function. His statement "*Sometimes the y = 0 is above the given function, but its limit remains as a and b right?*" clearly indicates that he understands there are cases where the function given is below the *x*-axis. Even though he did not write both cases to evaluate an area between two curves, he realized the existence of two different possibilities. He understands that the method involved to evaluate such an area will use the same limits, as in the case where the function is above the *x*-axis. However, he did not write the answer in the case when the graph is below the *x*-axis. He claimed he was careless in a lot of questions and forgot the lessons learned for not writing the second case. But is he really careless? Has he actually forgotten what he has learned in class? To affirm his claims, the following questions were posed to him.

In general, ELI claimed his unsuccessful attempts were due to his carelessness. However, for Question 12, he specifically relates his incomplete solution to his forgetfulness. Nevertheless, his interview dialogue tells the opposite, where he has not forgotten everything that he has learned. His responses imply his understanding about the concept of evaluating areas in two different regions. Unlike the answer written in his answer sheet, he was able to write a complete and perfect solution during the interview session. He knew how to evaluate an area separately, and he also understood how to evaluate a combination of more than one region. He managed to use the correct operation in combining the two regions, where he used an addition operation to combine them. In fact, he has also admitted that his poor performance in answering questions involving area was the result of last-minute test preparation. Waiting until the last minute to study implies cramming information. This tactic may sound ineffective, but Nonis and Hudson (2010) discovered the opposite finding in their research. Similarly, in this research, even though EL1 did not fully answer Questions 4 and 12, he managed to recall the related concept behind the idea of evaluating area between the curves.

Based on EL1 answers, it is logical to claim that the concept was internalized within his mind when he did the activities with the help of Maple software during the tutorial sessions. When asked about his experience after learning math with Maple, he said "*… I understand better whatever my lecturer has taught me because during the tutorial, my lecturer asked us to try all the activities using Maple, and followed by our own manual working… so when I revised them at home, I managed to understand.*" He added "*… also, all the basics help me a lot, when I understand the basic… if its limits are 1 to 3, for example, 0 to 1 plus 1 to 3…, at first, I didn't understand, I used Maple … ohhh … I got it. "Get Hint" in Maple Tutors is really helpful …*" Upon experiencing both strategies (learning mathematics with Maple and without Maple), he claims that the constraint of normal tutorial classes is in term of time limitation. On the other hand, the learning strategy using Maple software encourages the understanding of important concept according to his time management structure.

Other than EL1, a student in a high pre-knowledge integral calculus level (EH1) has also mentioned the advantage of using Maple in learning integral calculus. He has compared his friends' learning style before and after using Maple. "*I think Maple benefits all students. I observe, my friends who are weak … not actually they are really weak in learning, but they are actually lazy … they are not unintelligent, but they are not hardworking; they do not bother to concentrate, to focus … they don't even bother to ask even though they didn't understand anything at all …*" When asked about the effect of Maple on students' learning style, he added, "*They always say, math class is boring … sleepy … but with Maple, they have changed, they love to ask questions even for simple basic problems … hey … how to do this? … how to do this? … They even make their own effort to try.*

What is lacking in the EL1 answer for Question 4 was the uncertainty of the suitable process involved. This case could be related to the argument made by Star (2000): "Knowledge of procedures is measured by what a student does or does not do." In this case, EL1 has a problem with procedural understanding in answering Question 4. His inability to fully write the solution is well explained by his last minute study habits. Students need extra rehearsals to be fluent in mathematics (Hartlep, 2009). Thus, the fluency of procedural involved will be developed through consistent revisions. Obviously, last-minute preparations limit the number of questions attempted and, hence, restrict the amount of rehearsals done. A student from medium pre-knowledge integral calculus level (EM1) also commented that his friends prefer to study at the very last minute, "*I observe my friends' study at the very last minute, last night (a night before the test); they have just started to study lesson for week 9 (the introduction of integral calculus). There are a lot more subtopics … week 10 until week 1 … to start week 10; it was too late at night already … they love to study last minute.*" EH1 also mentioned "*…normally they (referring to his friends) say, math is so difficult… actually, they like to study last minute, and in my case, actually there is one problem, last time I think math is difficult … the actual reason is, I did not do the exercises consistently … that is the actual problem.*" To impose consistent study habits, Hartlep (2009) noted that students need to be given homework. EL1 also admitted that, when he was given an assignment, he will study more than usual. However, other than giving a regular basis assignment, in this study, students' study habits were also improved by changing the strategy in learning. In this case, EL1 agreed that tutorial sessions are helpful and the activities have helped him to better understand the concepts. As a result, his interest to revise the material at home has been developed.

Unlike EL1, EM1 is not clear about Questions 4 and 12. He found both questions confusing because, according to him, the questions did not provide complete information. He claimed that Question 4 did not provide the information regarding the boundary values of the given region. However, he managed to correctly write the answer by relating the question to the basic information learned in class. In other words, he was able to flexibly link the known information with his current situation's need. The two pieces of information were successfully combined to indicate the conceptual knowledge successfully developed in a student's mind (Hiebert & Lefevre, 1986). In this sense, his ability could be defined as his conceptual understanding about the substance involved in the evaluation area of regions.

He also found it difficult to interpret the information given in Question 12. He was unable to comprehend the information given and did not know what he supposed to find, despite reading the question many times. Even so, he managed to write a complete and correct solution for the question. He noted, "*but I remember my lecturer taught in class, there is one function above, the area is above, and area under the graph, I managed to recall the steps*," thus indicating that he mechanically solved the problem by visualizing the information. In this sense, he translated the written information into familiar visual interpretations learned in class. He responded consistently when he was asked to explain what he was thinking about when he wrote the first answer to Question 12. Once again, his response implies that his thinking is inclined toward translating words into visual form by saying, "*I think how the graph looks like … there is one graph below the x-axis and there is another graph above the x-axis. Therefore, if the graph is below the x-axis, the zero value minus f(x).*"

His thinking process indicates that, by using Maple in learning, the visual inputs fossilized in his mind faster than word inputs. Thus, these visual inputs seem to remain longer in his mind. In this sense, the advantage of using the technology has enhanced his thinking ability. He was able to develop a connection between known visual inputs with new word problems to make the problem into meaningful pieces of information. With that, he was able to reach a conceptual understanding of the related substance involved in evaluating the area between curves. In this sense, the conceptual knowledge was formed as a result and not as an initiator of learning (Aufschnaiter & Rogge, 2010). In this case, prior experiences have successfully promoted the intended concept formation. Nonetheless, his conceptual understanding was not developed visually per se but through a combination with his procedural fluency. His responses "*… I tried to apply the concept, and then there was a line … this one actually to find x value, right?*" and "*… To find the area. x is the value … the limit value I think,*" when he was asked about the objective of his explanation on finding the *x* value indicates his preference to solve the problem procedurally. His responses explain that his thinking style started with procedural fluency and gradually transformed into conceptual understanding.

EH1 responses toward the questions posed during the interview session indicate his confidence level is high. He knows what he is doing and understands why he took certain measures in evaluating the area. He shows his consistent revisions based on his responses "*Based on what did I learn, based on what did I remember…*" His constant rehearsals foster his procedural fluency and his conceptual understanding. He not only understands the process involved in evaluating an area but also is able to rationalize the reason why the first part of the answer has a negative sign. He indicates realizing the importance of consistent revisions when he said, "*… in my case, actually there is one problem, last time I think math is difficult … the actual reason is, I did not do the exercises consistently … that is the actual problem …*" He started to engage more in learning mathematics with the help of Maple software "*… at home if couldn't get the answer, I use Maple, using Maple Tutors to integrate product, I can detect if I didn't do it correctly … if I couldn't fully understand the steps, at least, I have the final answer …*" he added, "*but I will try to solve the question until I get the answer.*" In this case, Maple offers him a handrail to hold on building his confidence in solving problems in the new topic. However, he has suggested that, in order to maximize the potential of the software, the strategy should be introduced in other topics before integral calculus as well. Similar opinions have been suggested by EL1 and EM1, where they admitted to needing extra time to learn effectively. Lack of time provided has blocked the opportunity for students to develop their metacognitive awareness. Therefore, with a longer intervention period, students' metacognitive awareness may be improved.

CONCLUSION

Students who underwent the integral calculus lesson using Maple software as an aid in learning were found to benefit in procedural and conceptual understanding. Newly developed strategies have the objective to enhance students' conceptual understanding through class discussions and reflection activities. Maple software offers visual inputs that help students to translate the symbolic inputs into meaningful information. These visual inputs were found to absorb better in students' minds, and they reside longer in students' memories. These advantages were fully utilized by students involved in maximizing their potential in learning integral calculus. They were found to engage in learning activities voluntarily with their own initiatives. Also, Maple software gives them freedom to manage their own study time and, thus, increase their interest in learning. Although there are cases where students committed to last-minute study habits, they were still able to perform conceptually but still had problems with procedural fluency. The conceptual understandings were internalized during activities with Maple in class. Undoubtedly, students will face problems in performing the procedural part of the evaluation due to lack of rehearsal. As a result, students' metacognitive awareness cannot be optimized in this research. Students' metacognitive awareness may be enhanced if the learning time is longer. Furthermore, if these activities are implemented in other topics in engineering technology mathematics, students' mathematics performance, in general, may be improved and, thus, can help to increase the number of students who graduate on time. Therefore, the issue of inadequacy of numbers in the workforce related to developing the nation's industrial growth eventually will be reduced.

REFERENCES

ABET. (2011). Engineering vs. engineering technology. http://www.abet.org/engineering-vs-engineering-technology

Ali, A. A. A., Noor, M. J. M. M.., Abdullah, W. M. W., & Darusman, A. H.. (2009). Engineering Team: The Future Role of Engineering Technologists a Report of Study on the Status and Future Direction of Engineering Technology in Malaysia.

Aufschnaiter, C. V., & Rogge, C. (2010). Misconceptions or missing conceptions? *Eurasia Journal of Mathematics, Science & Technology Education, 6*(1), 3-18.

Ayub, A. F. M., Mokhtar, M. Z., Luan, W. S., & Tarmizi, R. A. (2010). A comparison of two different technologies tools in tutoring calculus. *Procedia Social and Behavioral Sciences 2*(-), 481-486.

Bergsten, C. (2008). On the influence of theory on research in mathematics education: the case of teaching and learning limits of functions. *ZDM Mathematics Education, 40*(1), 189-199.
Blank, L. M. (2000). A metacognitive learning cycle: A better warrant for student understanding? *Learning* 486-506.
Board of Engineers Malaysia, Institution of Engineers Malaysia, & Federation of Engineering Institution of Islamic Countries. (2003). "Technology Path" Blueprint for a highly competent engineering, technical workforce.
Bryant, R., Weiss, R., Orr, G., & Yerion, K. (2011). Using the context of algorithmic art to change attitudes in introductory programming. *The Journal of Computing Sciences in Colleges, 27*(1), 112-119.
Burton, M. B. (1989). The effect of prior calculus experience in "introductory" college calculus. *American Mathematical Monthly, 96*, 350-354.
Chang, C. C., & Chou, N. (2011). Effects of reflection category and reflection quality on learning outcomes during web-based portfolio assessment process: A case study of high school students in computer application course. *The Turkish Online Journal of Educational Technology, 10*(3), 101-114.
Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, New Jersey, USA: Lawrence Erlbaum Associates, Inc., Publishers.
Colonna, F., & Easley, G. (2011). Hints on how to improve mathematics instruction. *Journal of e-Learning and Knowledge Society, 7*(1), 7-20.
Davis, R. B. (1986). Conceptual and procedural knowledge in mathematics: A summary analysis In J. Hiebert (Ed.), *Conceptual and Procedural Knowledge: The Case of Mathematics* (pp. 265-300). Hillsdale, New Jersey: Lawrence Erlbaum Associates
Dubinsky, Ed. (1991). Reflective Abstraction in Advanced Mathematical Thinking. In D. Tall (Ed.), *Advanced Mathematical Thinking* (Vol. 11, pp. 95-126). Netherlands: Springer Netherlands.
Dubinsky, Ed. (2001). Using a theory of learning in college mathematics course. *Newsletter 12 0f TaLUM (Teaching and Learning Undergraduate Mathematics), 2001*(May), 10-15.
Dubinsky, Ed, & McDonald, M. A. (2001). APOS: A constructivist theory of learning in undergraduate mathematics education research. In D. Holton (Ed.), *The teaching and learning of mathematics at the university level* (Vol. 7, pp. 273-280). Dordrecht The Netherlands: Kluwer.
Fox-Turnbull, W. (2012). Learning in Technology. In P. J. Williams (Ed.), *Technology Education for Teachers* (pp. 55-92). Rotterdam, The Netherlands: Sense Publishers.
Grove, M. (2012). The mathematical transition: A multi-stage problem? *MSOR Connections, 12*(1), 15-18.
Haripersad, R. (2011). Deep and surface learning of elementary calculus concepts in a blended learning environment. *International Journal of Mathematics and Computers in Simulation, 5*(4), 291-298.
Hartlep, N. D. (2009). How do homework guides help students acquire procedural knowledge? http://www.unco.edu/ae-extra/2009/2/hartlep.html
Henderson, S., & Broadbridge, P. (2007). *Mathematics for 21st-century engineering students.* Paper presented at the AaeE Conference, Melbourne, Australia.
Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), *Conceptual and Procedural Knowledge: The Case of Mathematics* (pp. 1-27). Hillsdale, New Jersey: Lawrence Erlbaum Associates
Highfield, K., & Goodwin, K. (2008). *A Review of Recent Research in Early Mathematics Learning and Technology.* Paper presented at the Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia.
Ismail, K.M., & Puteh, M. (2008). *Engineering technology: A Malaysian case*. Paper presented at the International Conference on Engineering Education "New Challenges in Engineering Education and Research in the 21st Century", Pecs,Budapest,Hungary.
Kashefi, H., Ismail, Z., Yusof, Y. M., & Rahman, R. A. (2012). Fostering mathematical thinking in the learning of multivariable calculus through computer-based tools. *Procedia Social and Behavioral Sciences, 46*(-), 5534-5540.
Kember, D. (2000). Misconceptions about the learning approaches, motivation and study practices of Asian students. *Higher Education 40*, 99-121.
Lavicza, Z. (2010). Integrating technology into mathematics teaching at the university level. *ZDM Mathematics Education, 42*(1), 105-119.
LeBeau, B., Harwell, M., Monson, D., Dupuis, D., Medhanie, A., & Post, T. R. (2012). Student and high-school characteristics related to completing a science, technology, engineering or mathematics (STEM) major in college. *Research in Science & Technological Education, 30*(1), 17-28.
Lee, J. K. (2004). A case study of procedural and conceptual knowledge construction in a computer environment. *Journal of the Korean Society of Mathematical Education Series D: Research in Mathematical Education, 8*(2), 81-93.
Maharaj, A. (2010). An APOS analysis of students' understanding of the concept of a limit of a function.

Pythagoras 71(July), 41-52.
Mynbaev, D. K., Bo, C. C., Rashvili, R, Ya, K., & Liou-Mark, J. (2008). *Support of study on engineering technology from Physics and Mathematics*. Paper presented at the ASEE Mid-Atlantic Conference.
Noinang, S., Wiwatanapataphee, B., & Wu, Y. H. (2008). *Teaching-Learning Tool for Integral Calculus*. Paper presented at The 13th Asian Technology Conference in Mathematics, Suan Sunandha Rajabhat University, Bangkok, Thailand.
Osborne, J. (2007). Science education for the twenty-first century. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(3), 173-184.
Othman, J. (2010). *Engineering technology versus engineering, are they complimenting or competing? The Purdue University experience*. Paper presented at the A Half Day "Engineering Technology" Colloquium The Role of Engineering Technologist in Nurturing Innovative and Knowledgeable Leaders in High-Income Nation, Kuala Lumpur, Malaysia.
Özkan, E. M., & Ünal, H. (2009). Misconception in Calculus-I: Engineering students' misconceptions in the process of finding the domain of functions. *Procedia Social and Behavioral Sciences, 1*(1), 1792–1796.
Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching and assessing. *Theory into Practice, 41*(4), 219-225.
Salleh, T. S. A., & Zakaria, E. (2012a). The effects of integrating technology on students' conceptual and procedural understandings in integral calculus. *Asian Social Science, 8*(16), 8-16.
Salleh, T. S. A., & Zakaria, E. (2012b). Module for learning integral calculus with Maple: Lecturers' views. *The Turkish Online Journal of Educational Technology, 11*(3), 234-245.
Schraw, G., & Dennison, R. S. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology, 19*(-), 460-475.
Selden, A. (2005). New developments and trends in tertiary mathematics education: or, more of the same? *International Journal of Mathematical Education in Science and Technology, 36*(2-3), 131-147.
Vos, H., & Graaff, E. D. (2004). Developing metacognition: a basis for active learning. *European Journal of Engineering Education, 29*(4), 543-548.
Ward, J.P. (2003). Modern mathematics for engineers and scientists. *Teaching Mathematics and its Applications, 22*(1), 37-44.
Weller, K., Arnon, I., & Dubinsky, E. (2011). Preservice teachers' understandings of the relation between a fraction or integer and its decimal expansion: Strength and stability of belief. *Canadian Journal of Science, Mathematics and Technology Education, 11*(2), 129-159.
Wiwatanapataphee, B., Noinang, S., Wu, Y. H., & Nuntadilok, B.. (2010). An Integrated Powerpoint-Maple Based Teaching-Learning Model for Multivariate Integral Calculus. *International Electronic Journal of Mathematics Education, 5*(1), 5-31.
Yates, P. C. (2012). New strategies for teaching maths to chemistry students *Analytical and Bioanalytical Chemistry 21*(October), 1-6.
Zakaria, E, & Iksan, Z. (2007). Promoting cooperative learning in science and mathematics education: A Malaysian perspective. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(1), 35-39.