Pertanika J. Soc. Sci. & Hum. 23 (2): 375 -389 (2015)

PERTANIKA JOURNALS

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Musical Mnemonics to Facilitate Learning of Matriculation Biology: Light-dependent Reactions of Photosynthesis

Yeoh, M. P.

Selangor Matriculation College, 42700, Banting, Selangor, Malaysia

ABSTRACT

Learning Biology involves mastering declarative knowledge and mastering procedural knowledge. The 'Light-dependent Reactions of Photosynthesis' is a topic requiring procedural knowledge. Students have to remember the facts of the light-dependent reactions. They must also remember the order in which the steps of the reaction occur. Students of Malaysian Matriculation Colleges learn Biology in English, which is not their first language. As such, students have difficulty in remembering the light-dependent reactions of Photosynthesis. The purpose of this project is to help these students remember the facts correctly, and in the right order. The results of an independent samples t-test showed that this approach enabled students to consolidate their memory processes; t (146) = 21.08, p = 0.0005. The effect size was 0.8661. Based on the findings, the researcher proposed that musical mnemonics be used to facilitate remembering of other biological processes. As a learning tool, musical mnemonics must meet several criteria in order to be effective and the researcher has suggested the criteria. The results of this study imply that procedural knowledge in Biology can be successfully taught in English when teachers are innovative.

Keywords: Light-dependent Reactions, modelling, musical mnemonics, Photosynthesis, procedural knowledge

INTRODUCTION

Three related aspects of learning, constructivism, learning of procedural knowledge, and how people learn as explained in the Social Learning Theory (Bandura, 1977) are taken into consideration in this study.

ARTICLE INFO

Article history:
Received: 02 February 2014
Accepted:14 October 2014

E-mail addresses:
miranda@kms.matrik.edu.my; ezra118@gmail.com (Yeoh, M. P.)

ISSN: 0128-7702 © Universiti Putra Malaysia Press

Our existing knowledge is stored in our brain and encoded as 'constructs'. New learning is not understood unless it is connected to our existing concepts, knowledge and experience. Hence, new knowledge is linked to our existing knowledge and this process is constructivism. The links are stronger if they involve recent vivid engrossing, multisensory experience (Petty, 2009). In this study, musical mnemonics is the learning tool to engage learners with a song and to enhance memory potential (Cirigliano, 2013).

The second aspect is that learning facts or declarative knowledge is different from learning how to do something or procedural knowledge (Michael, 2006). The 'Light-dependent Reactions of Photosynthesis' is a topic that requires both declarative and procedural knowledge. Students have to remember the facts. They also have to remember the order in which the processes are taking place, and the sequence must be correct. This creates a greater challenge to master biological processes, like the Light-dependent Reactions of Photosynthesis.

The third aspect concerning learning, from the Social Learning Theory (Bandura, 1977), is that people learn through observing and imitating the behaviour and attitudes of significant others. Children watch and imitate parents, while students watch and imitate the behaviour of teachers, and this will enable students to achieve their learning objective (Yeoh, 2013c). Bandura (1977) calls this observational learning or modelling. The students observed and followed the researcher drawing a detailed diagram of the Light-dependent Reactions of Photosynthesis, from the information contained in the music mnemonics. This observational learning process required about 30 minutes.

Background and Purpose

Students of Matriculation Colleges in Malaysia learn Biology in English. All Sciences and Mathematics are taught and tested in English. Matriculation colleges continue to teach Sciences and Mathematics in English to prepare students for universities. However, English is not the first language of the majority of the students. Students have told the researcher that they are able to understand the processes or steps of Light-dependent Reactions of Photosynthesis. The researcher observed that the students were able to answer the structured and essay questions in the Biology tutorial book. They had prepared answers to the questions before the tutorial class, referring to their text books. Nonetheless, they said that they were not sure about how well they could remember when there were many more new chapters to be learned within the semester. Photosynthesis is the seventh chapter, of 12 chapters. They also mentioned that the names of organic substances (like 3-Phosphoglycerate, Glyceraldehyde 3-phosphate, Ribulose 5-phosphate, Ribulose bisphosphate, Plastoquinone, Plastocyanin) were long names, unfamiliar and difficult for them to remember. They have difficulty in retrieving the facts correctly and in the right order, in English, due to the fact that English is

not their mother tongue. Several of the researcher's students have even admitted that they have to learn in Malay and then translate the facts into English (Yeoh, 2013c).

English was used as the medium for Teaching and Learning of Science and Mathematics (PPSMI, the Malay acronym) from 2003 in schools and Matriculation colleges. In 2012, however, schools were allowed to use Malay Language, and many schools preferred to revert back to the use of the national language, Malay Language. By this means, school students would avoid having to learn in Malay and translate back to English, as done by the students involved in this study.

Research has shown that primary school students who are first taught Science in the native language (Malay, in this case) can achieve greater general knowledge of the subject (Science), if they are first taught the subject in the mother tongue (Engle, 1975). This is the advantage of teaching Primary Science in the mother tongue (Malay, in Malaysia). Other studies that showed parallel results on the advantage of the mother tongue in education of children were documented by Cummins (1979) and Butler and Marsh (1986). Yuen and Siu (2014), however, showed that although students became more proficient in English language (the second language) that was used as a medium for instruction of content subjects like Science, their performance in the content subjects suffered.

However, PPSMI is currently still in effect for 18 year old matriculation or pre-university students (the researcher was given this information at a meeting on 26-28 February 2014, organized by the Matriculation Division of the Education Ministry, for all the Heads of PPSMI in their respective colleges). Students who have been studying Science in schools in the national language admitted that they need help when the medium of instruction is changed to English. Hence, the purpose of this project is to enable these students to remember the facts of the Light-dependent Reactions of Photosynthesis correctly and in the right order, in English.

Although the studies reviewed, in the next section, show that mnemonics is very significant in improving the recalling of facts and improving test scores, research that has been carried out and documented by Malaysian researchers in this area is still limited. The researcher carried out a study on the effectiveness of musical mnemonics to facilitate students' learning of the Krebs Cycle of Respiration (Yeoh, 2012). Then, she went on to investigate students' recall of the Calvin Cycle of Photosynthesis (Yeoh, 2013a), Glycolysis (Yeoh, 2013b), and the Electron Transport Chain of Respiration (Yeoh, 2013c). The purpose of this project is to enable Matriculation students to recall the facts of Light-dependent Reactions of Photosynthesis correctly, and in the right order, in English.

LITERATURE REVIEW

This section discusses studies on learning and mnemonics. Bandura's Social Learning Theory (1977) has three core concepts.

The first core concept is that people learn by observation or modelling. The second core concept is that internal personal mental states are important to learning. Thus personal satisfaction or a sense of accomplishment positively influences learning and behaviour, and it is not just the external environment that plays a role in learning. This emphasis on internal mental states relates Bandura's theory to cognitive theories. Bandura's third core concept is that learning does not necessarily produce a permanent change in behaviour.

Bandura (1977) stated that human behaviour is mainly learned by observational learning or modelling. By observing parents and teachers, children get an idea of how new behaviours are performed. This coded information serves as a guide for subsequent action. In this research, the teacher was the live model, showing the behaviours of how the musical mnemonics (or song lyrics) could be used to draw a diagram of the Light-dependent Reactions of Photosynthesis (Figure 1).

The researcher realised that the intrinsic mental states of the students are important for learning to occur, as stated in Bandura's (1977) second core concept. Students need to actively assimilate the information in the mnemonics, or song, of the Light-dependent Reactions of Photosynthesis. Active learning is taking place when constructivism links are forged between new and existing knowledge by the students. Singing the mnemonics or song at a slow pace while drawing the diagram of the Light-dependent Reactions of Photosynthesis (Figure 1) would engage the eyes and ears, the sensory organs of learning. The researcher desired strong constructivism links to be forged in the minds of the students, through vivid, engrossing, multisensory experience (Petty, 2009).

Mnemonics may be defined as devices to enable students to remember information on various subjects, more easily and effectively, by connecting the new unfamiliar information that must be learned with information that is already known by the learner, with the use of visual and auditory cues (Mastropieri, Sweda, & Scruggs, 2000). Mnemonic strategies, including acrostics and acronyms, have facilitated young adult learners to recall information by making new information more familiar, meaningful and concrete. The young adult learners used acrostics and acronyms to improve their vocabulary knowledge (Bakken & Simpson, 2011).

Among English-speaking preschoolers (N = 36, 2 years), Shmidman and Ehri (2010) found that mnemonics facilitated the learning of foreign alphabets. They suggested that mnemonics was effective to reduce confusion, accelerate learning, besides enhancing long-term retention of foreign alphabets by the preschoolers (Shmidman & Ehri, 2010).

Mnemonics devices accelerated the acquisition of new knowledge in Elementary Accounting and helped to enhance formal reasoning (Laing, 2010). Just like Bakken and Simpson (2011), Laing (2010) also stressed that mnemonics devices such as acronyms and acrostics, narratives and

rhymes helped to make abstract concepts more meaningful and concrete.

An acronym that science students use to recall the colours of the rainbow is ROY G BIV. This helps them to recall the order of the rainbow colours correctly as Red, Orange, Yellow, Green, Blue, Indigo and Violet (Bakken & Simpson, 2011). This same acronym was used by the author while teaching the visible light spectrum in Photosynthesis.

An acrostic is a form of writing in which the first letter or syllable spells out a word or a message. Acrostics is catchy to enable students remember something important. This was used by the researcher for students to remember the sequence of organic compounds of the Krebs cycle (Yeoh, 2012). The sentence was: 'Citrus, Isobel, Ketty, sing sulk fume (on) male oxen.' Using this sentence, students can easily remember the sequence from Citrate, Isocitrate, Ketoglutarate, Succinyl CoA, Succinate, Fumarate and Malate. Students can also recall easily the number of Carbon atoms in each of these compounds because this is provided by the number of letters in the names [Citrus, Isobel, Ketty, sing sulk fume (on) male oxen]. By this, they remember that Isocitrate has 6 Carbon atoms in its molecule, and Ketoglutarate has 5 Carbon atoms in its molecule. This also reminds the students that a decarboylation reaction has occurred, that needs a Decarboxylase enzyme. Similarly, from Ketoglutarate to Succinyl CoA, another decarboylation reaction has taken place that needs another Decarboxylase enzyme. This clue is provided by putting a 5 letter word 'Ketty' for Ketoglutarate, and a 4 letter word 'Sing" for Succinyl CoA. 'Sulk' is another 4 letter word used for succinate. 'Fume' sounds like fumarate, another 4-Carbon compound; and 'male' sounds like malate, also a 4-Carbon compound (Yeoh, 2012).

The sentence: 'Citrus, Isobel, Ketty, sing sulk fume (on) male oxen' was set to the tune of 'Old MacDonald had a farm' that most students are already familiar with, making it a musical mnemonic as well (Yeoh, 2012). The use of musical mnemonics by the researcher to teach Biology (Yeoh, 2012; Yeoh, 2013c) is parallel to the study reviewed on the effectiveness of musical mnemonics as a powerful learning tool in medicine and health science (Cirigliano, 2013).

Biology is basic science for Medical Studies that comprises Anatomy, Biochemistry pathways, Surgery, Pharmacology, Clinical procedure, Diagnostics, Medication and Treatment. As such, Medicine is a broad, diverse field and medical students need devices for memorisation and recall (Cirigliano, 2013). Hence, Medicine has a history of mnemonics composed by students and instructors. Medical students need the memory aids, and many mnemonics, including musical mnemonics have been placed on online databases such as http://www.medicalmnemonics.com. Anatomy mnemonics and Pharmacology mnemonics are available at www.doctorshangout.com. (The webpages were assessed on 8 March 2014). Just like medical students, Biology

students also need mnemonics as memory aids (Yeoh, 2012; Yeoh, 2013c).

Since song (and music) has been a form of communication, is present in every culture, and has from ancient times been the medium to pass down significant stories from one generation to the next (Dunlap & Lowenthal, 2010), it is not surprising that it is useful to employ musical mnemonics as a learning tool. In this study, song that has the ability to engage students' attention and to enhance their memory potential is used as a learning tool for students to remember the Light-dependent Reactions of Photosynthesis in Biology, just as it was used for the study of Health Science (Cirigliano, 2013). Cirigliano (2013) stated that instructors or teachers played a major role in using musical mnemonics, from a survey of ten music mnemonics on YouTube. In this study, it is the teacher who created the music mnemonics for the Light-dependent Reactions of Photosynthesis. Cirigliano (2013) suggested that more robust research like meta-analysis could confirm the value of mnemonics in the learning of Health Science and Medicine.

It is necessary to emphasise the limitations of mnemonic strategies. Mnemonics is useful only for stimulating recall, but it is not a comprehension strategy (Bakken & Simpson, 2011); mnemonics does not help students to understand. The students involved in this study have been given a lecture on Light-dependent Reactions of Photosynthesis, and they have also had practice in answering structured and essay questions on Photosynthesis. They admitted that they had understood the Light-dependent Reactions, but they said that they could not remember. With the musical mnemonics that they were taught for the Light-dependent Reactions, the students admitted that they enjoyed the learning. This shows that the song for the Light-dependent Reactions that has engaged them has enhanced their recall potential, and is an effective learning tool in this academic setting (Cirigliano, 2013; Yeoh, 2012; Yeoh, 2013a; Yeoh, 2013b; Yeoh, 2013c).

Letter-phonetic mnemonic devices (acronyms and acrostics) have also been used to facilitate nurses to recall basic knowledge in nursing education (Onur, Ali, Yunus & Musa, 2013). The research investigated the effect of the letter/phonetic method on nurses' attainment of basic knowledge of the healthcare system, and nurses' recall of this basic knowledge (N=76).

In that study, only the experimental group (n=39) was taught using letter-phonetic mnemonics. Both the experimental (n=39) and the control groups (n=37) were tested on healthcare system, health teams and the role of nurses. They were given the same test (i.e., the Attainment test) after the study. Using a t-test, the researchers showed that there was a significant difference between the experimental and control groups ($t = 9.35$, $p = 0.0005$), in favour of the experimental group that employed letter-phonetic mnemonics (Onur *et al*., 2013).

Three weeks after the instruction, the participants were tested again; and the same Attainment test was given as a Retention

test (Onur *et al*., 2013). Using a t-test, the researchers, once again, found a significant difference between the experimental and control groups, in favour of the experimental group that employed letter-phonetic mnemonics ($t = 12.73$, $p = 0.0005$).

Acronym mnemonics was also used by Schumacher (2005) in nursing practice. Before hanging or pushing medication, nurses, pharmacists, physicians, healthcare providers, and even patients themselves should ask: Do your CATS PRRR?; where the acronym (CATS PRRR) represents Compatibilities, Allergies, Tubing, Site, Pump, Right Rate, Release, and Return and Reassess. This acronym is to facilitate nurses to remember the many facets of safe techniques for intra venous medication preparation, administration, and the correct use of the various intra venous pumps. Again, it is emphasised that the common feature of the mnemonics used by Biology students, medical students and nurses is that they are devices for recalling, and not for comprehension. Mnemonics should not replace regular lectures and tutorial classes that place importance on students' learning and understanding and constructivism, but mnemonics could facilitate Biology students, medical students and nursing students to recall information (Cirigliano, 2013; Onur *et al*., 2013; Yeoh, 2012; Yeoh, 2013a; Yeoh, 2013b; Yeoh, 2013c).

Research on physically impaired persons has also shown that musical mnemonics facilitated superior learning and memory retention in patients with multiple sclerosis. These patients were able to recall and sing back the words. Thaut, Peterson and McIntosh (2005) suggested that musical learning accesses compensatory pathways for memory functions. Music learning could have conferred a neuro-physiological advantage through the stronger synchronisation of neuron assemblies underlying verbal learning and memory. The authors concluded that melodic-rhythmic templates in music could drive internal rhythm formation in recurrent cortical networks that are involved in learning and memory (Thaut *et al*., 2005; Yeoh, 2013c).

Simmons-Stern, Budson and Ally (2010) found that musical mnemonics enhanced attention and improved memory in patients of Alzheimer Disease (AD). Music processing function is generally spared by the neuron degeneration of AD patients. These AD patients showed better recognition accuracy for the lyrics that were sung as compared to spoken lyrics of unfamiliar children's songs. The authors proposed that the brain areas serving music processing are not affected by AD, allowing a more holistic encoding that facilitated recognition, and that music heightens arousal of AD patients producing better attention and improved memory (Simmons-Stern *et al*., 2010; Yeoh, 2013c).

The first effort of the researcher to investigate the effectiveness of musical mnemonics to facilitate the learning of Matriculation Biology was on students' retrieval of facts of the Krebs cycle of respiration (Yeoh, 2012). On this occasion, the researcher used a pre-test post-test procedure. A pre-test was administered.

Then, the researcher proceeded to teach them the music mnemonics (discussed earlier in his review) and showed them on the Interactive Electronic Equipment (IEE) scanner how to employ the mnemonics as an aid to recall the facts and processes of the Krebs cycle. After that, a post-test was carried out. The data collected at this meeting was analyzed using the paired sample t-test.

The researcher found that musical mnemonics did help Biology students to improve their scores. The pre-test mean score for the sample of 145 students was 4.12 (SD = 4.75) of a total of 20. The mean score at the post-test increased to 13.81 (SD = 3.16). The paired samples t-test used in that research showed a significant improvement in the post-test scores, $t(144) = 23.45$, $p = .0005$). She concluded that musical mnemonics was effective in helping students remember the Krebs cycle and implied that the teaching of Biology in English is facilitated when teachers are innovative (Yeoh, 2012). However, after the first study, the design of subsequent studies, including this present study, is improved by including a control group (Yeoh, 2013a; Yeoh, 2013b; Yeoh, 2013c).

METHODOLOGY

Details of Innovation

To enable students to remember the Light-dependent Reactions of Photosynthesis, the researcher used the song below. It was a variation of 'The Sound of Music'; and sixteen short lines were sufficient to describe the Light-dependent Reactions.

'PSII absorbs light, electrons get excited,
Electrons rise up to primary acceptor of PSII;
Electrons pass through ETC of Pq, cytochromes and Pc,
ATPs produced.

PSI absorbs light, electrons get excited,
Electrons rise up to primary acceptor of PS I;
Electrons pass through ETC of Fd, cytochromes and Pc,
ATPs produced.

When PS I works on its own, only ATPs are produced,
This is cyclic photophosphorylation
When PS I works with PS II, electrons may pass through
Another pathway, through ferredoxin to reduce $NADP^+$

In this non-cyclic process, NADPH are produced,
Catalyzed by $NADP^+$ reductase enzyme;
With hydrogen released from photolysis of water,
The electrons go to PS II.'

Since the constructivism links are also strengthened when they are used repeatedly by the learners to describe and explain (Petty, 2009), the researcher encouraged students to sing the mnemonics and teach their friends.

Besides musical mnemonics, the researcher had silently used 'modelling' (Bandura, 1977). Students observed and imitated the behaviours that enabled the researcher to draw a detailed diagram of the Light-dependent Reactions of Photosynthesis just from the information contained in the mnemonics (Fig.1). After all, learning is essentially a social activity and we learn by direct verbal instruction and by observing teachers and peers (Bandura, 1977; Yeoh, 2013c).

Implementing the Research

The researcher met 148 students from eight tutorial classes at a late evening class on Monday, 18 February 2013; it was the 11th week of the semester. All the students had had lessons on Photosynthesis in week 9, and had done tutorial exercises during week 10 of the semester.

The students were randomly assigned to the control and experimental groups so that the control group and the experimental group would have equal number of students. Each

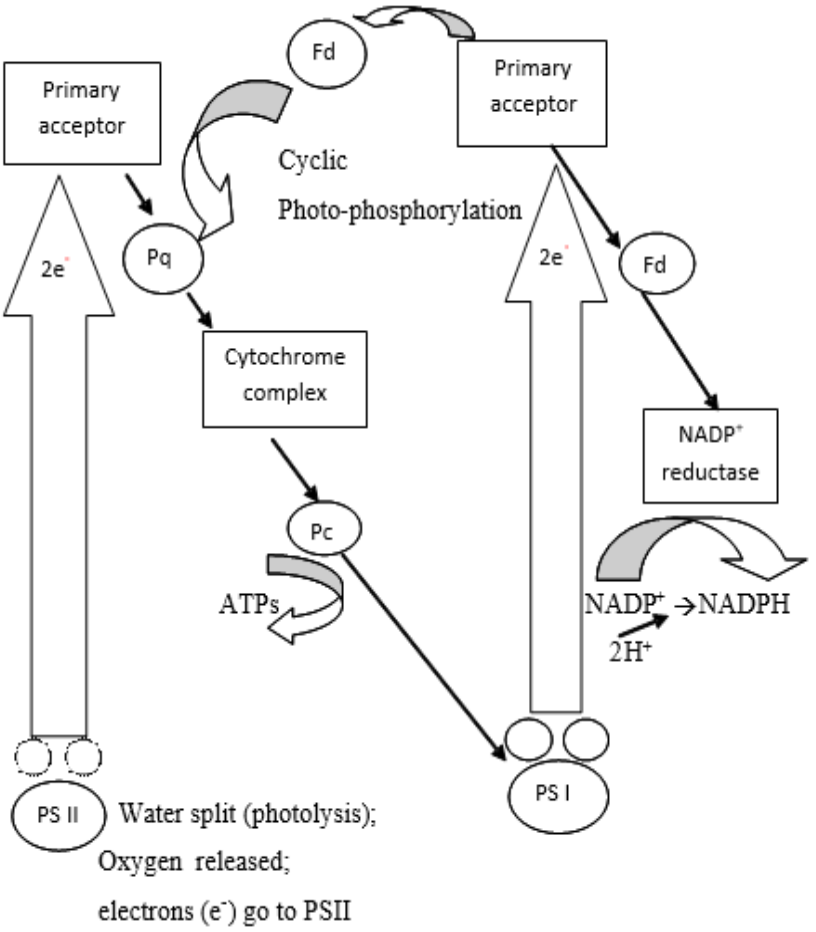

Fig.1: The light-dependent reactions of Photosynthesis, drawn from the musical mnemonics

student picked up a folded piece of paper. A 'C' would mean that he/she would be in the control group, while an 'E' would assign the student to the experimental group (Yeoh, 2013c). The control group was asked to go to the next empty room and learn the Light-dependent Reactions of Photosynthesis, in a conventional manner from the book and notes, while the experimental group was taught the musical mnemonics (simply called a 'bio-song') for Light-dependent Reactions of Photosynthesis.

The researcher also showed them (the experimental group) how to employ the song as an aid to draw and label a diagram of the Light-dependent Reactions of Photosynthesis. The group had the opportunity to observe and follow the researcher in drawing a detailed diagram from the information in the mnemonics (Fig.1).

When the control group came back in about half an hour, a short test was administered to all the students. There was no communication between the experimental and control groups that the researcher observed. The experimental group sat on the right side of the aisle of the lecture theatre, while the control group sat on the left of the aisle. For the test, the students were required to answer 15 short questions (see Evaluation) and to label five structures on the blank diagram of the Light-dependent Reactions of Photosynthesis (Figure 2). This would show whether they could apply the information in the songs to answer the questions. If the students only memorised, they would probably be writing the song.

After all the test papers had been collected, the researcher taught the control group the musical mnemonics and showed them how to use it to draw and label a diagram of the Light-dependent Reactions of Photosynthesis on the scanner. It was the right way to make up for their being in the control group. Some students of the experimental group sat quietly and listened attentively; and some sang together with the control group. In about fifteen minutes, when the control group were able to manage the song, all the students were asked to sing together, and they sang happily. The data were analysed for both groups. All the statistical analyses were carried out using SPSS. Finally, to facilitate further research, a video CD of the mnemonics was created using Windows Movie Maker (Yeoh, 2013c).

Evaluation

All the questions were to be answered. The questions were set to emphasise the importance of the sequence of the reactions of the Light-dependent Reactions of Photosynthesis.

Section A: Answer all the questions:

Q1. What happens to electrons when PSII absorbs light?

Q2. Where do these electrons go?

Q3. What are the components of this ETC of photosynthesis?

Q4. What happens to electrons when PSI absorbs light?

Q5. Where do these electrons go?

Q6. What are the components of this ETC?

Q7. What is produced when PSI works on its own?

Q8. What is the name for this reaction in Q7?

Q9. What happens when both photosystems work together?

Q10. What is reduced in the reaction in Q9?

Q11. What is the name for this reaction?

Q12. What is produced in the same reaction?

Q13. What is the enzyme involved in this reaction?

Q14. What is the source of hydrogen ions?

Q15. Where do the electrons go to?

Section B: Name the following substances or processes labeled A to E on the diagram of the Light-dependent Reactions of Photosynthesis (Fig.2).

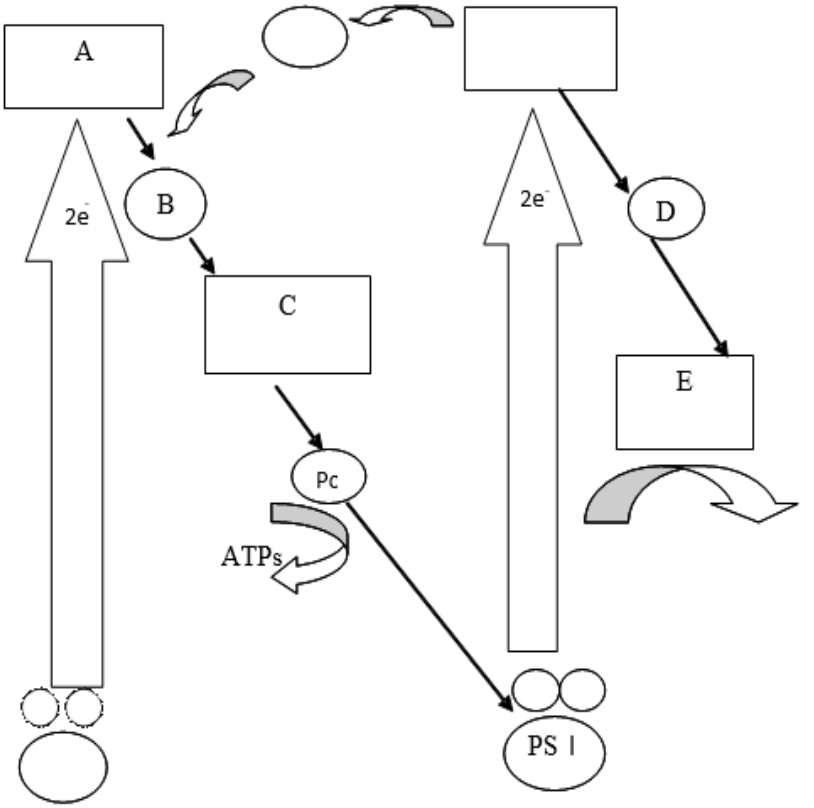

Fig.2: Evaluation on the light-dependent reactions of Photosynthesis

RESULTS AND DISCUSSION

The results showed that the mean score for the control group of 74 students was 2.89 (minimum = 0, maximum = 13 of a total of 20, while the standard deviation (SD) was 3.74; whereas the mean score for the experimental group sample of 74 students was 15.34 (minimum = 7, maximum = 20 of a total of 20, SD = .44). Generally, the students of the control group seemed to get the answers to the first two questions of Section A, and correctly label the Primary acceptor in Section B. However, the experimental group was more consistent, better able to answer Section A correctly and label the organic substances in Section B of the Evaluation.

Using SPSS, Levene's test showed that equal variances could be assumed, F=.130, p=.719. Independent Samples t-test showed a significant difference between the two groups t(146) = 21.077, p = .0005. The effect size was 0.8661 (Becker, 2013). The results showed the research has a large effect (Cohen, 1992), and that musical mnemonics is effective to enable students to the processes of the Light-dependent Reactions of Photosynthesis by consolidating their memory processes. In a previous research on mnemonics for teaching the Electron Transport Chain, a smaller effect size of 0.4965 was obtained (Yeoh, 2013c).

The results are in line with the literature reviewed on mnemonics. Bakken and Simpson (2011) has stated that mnemonics enabled students to remember information by making the information more familiar, more meaningful and concrete; that mnemonics was applicable to an array of subject areas; and useful with young adult learners that this research focused upon.

The results of this study are similar to the research by Onur *et al*. (2013), who reported that letter-phoenetic mnemonics, including acronyms, were highly effective in boosting nurses' recall in Basic Knowledge acquisition. They reported the t-values of the Attainment test and the Retention test that were carried out after three weeks. In both the tests, learning with mnemonics facilitated recall. However, the present study did not include a Retention test; and it would be a new idea that the researcher is curious to implement with future cohorts of Matriculation students.

With the use of musical mnemonics for learning Biology, this researcher is sharing the idea of other educators and instructors of Health Science and Medicine (Cirigliano, 2013). The researcher has encouraged her students to create their own mnemonics, and some of her students have taken up the challenge to create music mnemonics for learning the *Lac* Operon reactions (Yeoh, 2013d).

Even though the respondents in this study are physically normal (Cirigliano, 2013), not impaired by AD as in Simmons-Stern *et al*. (2010) nor impaired due to multiple sclerosis (Thaut *et al*., 2005), they have a handicap, in that English is not their mother tongue. However, mnemonics facilitated their recall of the Light-dependent Reactions of Photosynthesis. The results of this study are parallel with previous research,

including that carried out by the same researcher on the effectiveness of music mnemonics in teaching the Krebs cycle (Yeoh, 2012). The results are also in line with the studies concerning students' ability to remember other biological pathways, namely, the Calvin Cycle (Yeoh, 2013a), Glycolysis (Yeoh, 2013b) and Electron Transport Chain (Yeoh, 2013c).

CONCLUSION

The result of this study is parallel to other studies on mnemonics that have been reviewed. Musical mnemonics had facilitated students to recall the facts of the Light-dependent Reactions of Photosynthesis correctly and in the right order, in English. The findings are in line with previous studies that have been reviewed, employing mnemonics to facilitate memory recall.

Based on the findings, the researcher proposed that musical mnemonics be used to facilitate learning and recall of other biological processes. Students should be encouraged to be more independent and to compose their own mnemonics. As teachers, we are doing innovative teaching towards the aim of creating independent and innovative learners (Yeoh, 2013d).

Furthermore, since we are using musical mnemonics as a memory tool, it implies that several criteria should be met in order that the mnemonics will be effective. It is necessary that the lyrics be correct and concise or as brief as possible because that will help students to learn and recall more easily. Students should be able to draw a flow chart or diagram of the biological process from the lyrics of the mnemonics. From the diagram, they will be able to explain the biological process in simple English without omitting the important facts. As for the melody, the researcher suggests that it should be simple and familiar or at least easy to learn. The rhythm of the song should allow the key words to be uttered clearly. The researcher had expressed to her students the hope that they would bear these criteria in mind whenever they needed to create their own musical mnemonics to facilitate memory recall in the future. It may be that their self-created mnemonics be the most effective to facilitate their own learning and recall.

The results of this study imply that Biology can be successfully taught in English when teachers are innovative. This is important to the researcher, in view of the fact that future cohorts of Matriculation students from 2014/2015 will be those who were not required to learn school science and mathematics in English. The exposure of these students to English is not likely to be better than the batch of students involved in this study. Thus, the researcher expects a greater challenge, and will need to facilitate students' recall of Biological processes, using musical mnemonics.

Despite this, the study has shown that Biology, a 'wordy' subject, can be taught in an environment where the mother tongue is not English. This study also implies that the learning of Biology is facilitated by musical mnemonics. Mnemonics is a useful tool that can be employed by Biology teachers

who carry out the teaching of science and mathematics in English to prepare students for university education where the lingua franca is English.

REFERENCES

Bakken, J. P., & Simpson, C. G. (2011). Mnemonic Strategies: Success for the young adult learner. *The Journal of Human Resource and Adult Learning 7*(2), 79-85.

Bandura, A. (1977). *Social Learning Theory*. New York: General Learning Press.

Becker, L. (2013). *Effect Size Calculators*. Retrieved May 1, 2013, from http://www.uccs.edu/~lbecker/

Butler, S., & Marsh, H. (1986). Reading and Arithmetic Achievement in Primary Years for Students from Non-English-Speaking Families: A Seven-Year Longitudinal Comparison. *Australian Journal of Education, 30*, 23-44. doi: 10.1177/000494418603000102

Cirigliano, M. (2013). Musical mnemonics in health science: A first look. *Medical Teacher, 35*(3), e1020 - e1026. doi:10.3109/0142159X.2012.733042

Cummins, J. (1979). Linguistic Interdependence and the Educational Development of Bilingual Children. *Review of Educational Research 49*, 222-251. doi: 10.3102/00346543049002222

Dunlap, J. C., & Lowenthal, P. R. (2010). Hot for teacher: Using digital music to enhance student's experience in online courses. TechTrends, 54(4), 58-73. doi: 10.1007/s11528-010-0421-4

Engle, P. (1975). Language medium in early school years for minority language groups. *Review of Educational Research, 45*(2), 283-325. doi: 10.3102/00346543045002283

Laing, G. (2010). An empirical test of menmonic devices to improve learning in elementary accounting. *Journal of Education for Business, 85*(6), 349-358.

Mastropieri, M. A., Sweda, J., & Scruggs, T. E. (2000). Putting mnemonic strategies to work in an inclusive classroom. *Learning Disabilities Research and Practice, 15*(2), 69-74. doi: 10.1207/SLDRP1502_2

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*, 159-167. doi:10.1152/advan.00053.2006

Onur, K., Ali, M. S., Yunus, E. O., & Musa, O. (2013). The Impact of Mnemonic Devices on Attainment and Recall in Basic Knowledge Acquisition in Nursing Education. Mevlana International *Journal of Education, 3*(4), 265-278.

Petty, G. (2009). *Evidence Based Teaching*, 2nd Edition. Nelson Thornes: Cheltenham.

Schumacher, D. L. (2005). Teaching tips: do your CATS PRrr? A mnemonic device to teach safety checks for administering intravenous medications. *Journal of Continuing Education in Nursing, 36*(3), 104-106.

Shmidman, A., & Ehri, L. (2010). Embedded picture mnemonics to learn letters. *Scientific studies of reading, 14*(2), 159-182.

Simmons-Stern, N. R., Budson, A. E., & Ally, B. A. (2010). *Music as a memory enhancer in patients with Alzheimer's disease*. Retrieved May 1, 2013, from http://www.ncbi.nlm.nih.gov/ pubmed/

Thaut, M. H., Peterson, D. A., & McIntosh, G. C. (2005). *Temporal entrainment of cognitive functions: musical mnemonics induce brain plasticity and oscillatory synchrony in neural networks underlying memory.* Retrieved May 1, 2013, from http://www.ncbi.nlm.nih.gov/pubmed/

Yeoh, M. P. (2012, November 19-21). *The Effectiveness of Musical Mnemonics in Teaching Biology: Krebs' Cycle*. Paper presented at IPGM International Convention for Teacher Learning and Development, Pearl International Hotel, Kuala Lumpur.

Yeoh, M. P. (2013a, October 22-24). *Musical Mnemonics to Facilitate the Learning of Matriculation Biology: The Calvin Cycle.* Paper presented at National Convention of the Teacher Division, Ministry of Education, Malaysia, Le Grandeur Hotel, Senai, Johore Baru, Malaysia.

Yeoh, M. P. (2013b, November 11-14). *Musical Mnemonics to Facilitate the Learning of Matriculation Biology: Glycolysis*. Paper presented at 5th CoSMed International Convention, SEAMEO RECSAM, Penang, Malaysia.

Yeoh, M. P. (2013c, November 11-14). *Musical Mnemonics to Facilitate the Learning of Matriculation Biology: Electron Transport Chain*. Paper presented at 5th CoSMed International Convention, SEAMEO RECSAM, Penang, Malaysia. doi: 10.13140/2.1.1068.5449

Yeoh, M. P. (2013d). Facilitating cooperative learning among Matriculation Biology students. *Learning Science and Mathematics, 8*, 1-9.

Yuen, Y. L., & Siu, E. (2014). A Meta-Analysis of the Effectiveness of English-Medium Education in Hong Kong. *Review of Educational Research, 84,* 47-73. doi: 10.3102/0034654313499615