MUSICAL MNEMONICS TO FACILITATE THE LEARNING OF DNA REPLICATION

Miranda Yeoh Poh Khoon
Biology Unit, Kolej Matrikulasi Selangor
Kementerian Pendidikan Malaysia
<miranda@kms.matrik.edu.my>

Abstract

Most of the literature on mnemonics showed that mnemonics may facilitate learning and recall of respondents of different age groups. Matriculation students in Malaysia learn Biology in English, a non-native language, and they have difficulty in recalling the facts and the correct order of events. DNA replication is a key biological process requiring procedural knowledge. To the best of knowledge, there has been no research concerning the effect of musical mnemonics on students' recall of this topic that has been reported. In response to the education policy of teaching mathematics and science in English (ETeMS), the aim of this study was to use musical mnemonics to enable the students recall of the processes involved in DNA replication; in English. Altogether, sixty two students, aged 19 years, participated in this study; 31 each, in both the control and experimental groups. An independent samples t-test was used. The experimental group performed significantly better than the control group. The results indicated that musical mnemonics facilitated recall of the facts of DNA replication process among Matriculation students. The researcher concluded with reference to the education policies of ETeMS and 'Memartabatkan BM dan Memperkasakan BI' (MBMMBI) that are currently in force, in Matriculation colleges and schools respectively, in Malaysia.

Keywords: DNA replication; Procedural knowledge; Musical mnemonics; Biology education; Education policies in Malaysia

Introduction

Our existing knowledge is encoded as "constructs" and stored in our brain. New information needs to be linked to existing concepts and knowledge by the learner. Constructivism links that are forged will be stronger if the learning process involves vivid, engrossing, and multisensory experiences (Petty, 2009). In the present study, musical mnemonics is used to engage learners with a song, an auditory experience, that could strengthen constructivism links and facilitate learning by enhancing memory recall (Cirigliano, 2013; Miendlarzewska & Trost, 2014; Yeoh, 2014a, 2014b).

A second aspect is that the learning of declarative knowledge (or facts) is different from the learning of procedural knowledge, or how to do something (Michael, 2006). DNA replication is a topic requiring both declarative and procedural knowledge. The students need to recall the facts. In addition, they must remember correctly the order or sequence of the processes. This increases the difficulty of the respondents to learn Biology in English (a non-native language) when it comes to explaining biological reactions that require the ability to use declarative and procedural knowledge (Yeoh, 2012, 2013a, 2013b, 2013c).

A third aspect concerning learning is that learning also takes place, in some measure, through the observation and imitation of the behaviour of other significant people. This is explained in

Bandura's Social Learning Theory (Bandura, 1977). In learning situations at home, children observe and imitate the behaviour of parents. In biology classrooms, students observe and imitate the behaviour of teachers to produce labelled scientific drawings as well as detailed descriptions and explanations to achieve their learning objectives. Bandura (1977) called this observational learning process as "modelling". In this study, respondents observed and followed the teacher in drawing a diagram of DNA replication from the lyrics contained in the musical mnemonics. The process of teaching students the musical mnemonics required about 30 minutes, and has been helpful for Matriculation students to recall several biological pathways (Yeoh, 2014c, 2015a, 2015b).

Background of Study in Relation to Education Policies in the Country

The 'English in the Teaching of Mathematics and Science' (ETeMS or PPSMI, its Malay acronym) educational policy was introduced in 2003 by the fourth Prime Minister, Dr. Mahathir Mohamad. As a consequence, school students and students of Matriculation Colleges at pre-university, or K 12 level, learn Biology in English. However, the policy seemed to be entirely foreign to the mindset of many persons, particularly to those who called themselves "language nationalists". They were sceptical about the feasibility of ETeMS, citing the low level of English proficiency among school teachers and little interest in learning English among school students (Alwis, 2005). Later research did show that many school teachers were not sufficiently competent, did not make much use of the "Buddy Support System" that was implemented to help teachers overcome the language difficulties, and lacked confidence for the task of teaching Mathematics and Science in English, although there were also some technical problems related to the courseware (Azmi & Maniam, 2013).

The ETeMS or PPSMI policy was replaced with another education policy, 'Empowering Malay Language, Enhancing English Language' *('Memartabatkan Bahasa Melayu dan Memperkasakan Bahasa Inggeris'* or abbreviated as MBMMBI); hence, beginning in 2012, schools reverted back to using the national language. But Matriculation colleges continued with ETeMS or PPSMI policy (Yeoh, 2014a). The authors noted that the change in the education policy from ETeMS in 2003 to MBMMBI since 2012 would have reduced the time of formal classroom communication and interaction in English in schools, for students, beginning with the 2104/2015 batch of Matriculation students.

Level of Competency of Matriculation Students in English

Although English is not the native language of the 19 year old students in this study, they revealed that they were able to comprehend the processes taking place in DNA replication. This was in line with Prophet and Dow (1994) who found that when the second language (English) was used as the medium of instruction during science lessons, it had a significant effect on concept attainment for Form One students (13 years old), but no significant impact on concept attainment for Form Three school students in Botswana (15 years old).

However, other research showed that elementary school students who were first taught Science in the mother tongue can more easily achieve a vast knowledge of the subject (Engle, 1975). Similar studies that showed an advantage of the native language in education of children were documented by Cummins (1979), Butler and Marsh (1986), as well as Yuen and Siu (2014).

Matriculation students had learned English for eleven years of primary and secondary school. The researcher observed that the students were able to answer some of the structured and essay questions during the tutorial class. They had prepared answers to the questions ahead of the tutorial class, but they could have just copied answers from the text book. However, the

students were anxious and unsure how well they could still remember all the biological processes within the topic "Expression of Biological Information" when there were four more chapters to be learned within the semester. The topic "Expression of Biological Information", including DNA replication as a sub-topic, is the sixth chapter, of a total of ten chapters.

The students confessed difficulties in recalling the facts of DNA replication correctly and in the right sequence, mainly due to the fact that they do not think in English since English is not their mother tongue. The students had a tendency to discuss in the mother tongue; and at these discussions among themselves, only the Biology terms would be spoken in English. This lack of usage and lack of familiarity with the language probably contributed to their difficulty in remembering the biological processes in English, as it required familiarity with the linking words besides the Biology terms. The teacher had been teaching them in English and had encouraged them to communicate, formally and informally, in English (Yeoh, 2014a; 2014b; 2014c; 2015a; 2015b).

Requirements of the Biology Syllabus

The syllabus required students to be able to describe the mechanism of DNA replication and the enzymes involved. This description required students to include the unwinding of parental DNA, parental strand acting as template, synthesis of RNA primer, joining of DNA nucleotides to the exposed bases by specific base pairing, formation of leading and lagging strands, and the direction of strand formation from 5' to 3'. The major enzymes and proteins involved (e.g. Helicase, Single-strand binding protein, Topoisomerase or Gyrase, Primase, DNA polymerases and DNA ligase) and their functions were also needed (Reece et al., 2011; Matriculation Division, 2012).

Students were required to answer all exam questions in English, although a translation was provided in the national language. Most students chose to answer in English; and an analysis over the last five years by the Matriculation Division of the Education Ministry showed that around 95% of students used English in the mid-semester and final exams.

Objective of Study and its Significance

The objective of this project is to enable pre-university Malaysian students to whom English is non-native, to recall the facts of DNA replication correctly. Students needed also to recall the processes in the correct order, in English (Yeoh, 2014b, 2015b). The research question is "Would the musical mnemonics be effective to facilitate recall of the steps in DNA replication among the students?"

The review of literature in the next section showed that mnemonics were useful in facilitating memory recall among respondents of various age groups of students across various cultures and countries (Bakken & Simpson, 2011; Cirigliano, 2013; Garcia & Herrera, 2012; Stagg & Donkin, 2015; Yeoh, 2015a, 2015b; Zheng, 2015). Although the evidences reported that mnemonics are very significant in improving the remembering of facts and improving test scores (Yeoh, 2014a, 2014b), there have not been many studies documented by Malaysian educators. To our knowledge, the effect of using musical mnemonics was investigated for students' recall of the Krebs cycle (Yeoh, 2012), Calvin Cycle of Photosynthesis (Yeoh, 2013a), Glycolysis (Yeoh, 2013b, 2014c), Electron Transport Chain of Respiration (Yeoh, 2013c, 2015a), Transcription of RNA (Yeoh, 2014a), Protein Synthesis (Yeoh, 2104b) and Light-dependent Reactions of Photosynthesis (Yeoh, 2015b). For this research on students' recall of DNA replication, the researcher also chose to use musical mnemonics.

This research is significant because DNA replication is a key process, and a challenging first sub-topic that requires mastery of procedural knowledge within the chapter "Expression of Biological Information". If students could use musical mnemonics to recall DNA replication, they would not be too anxious about mastering sub-topics like Transcription of RNA or the Translation process of Protein synthesis (Yeoh, 2014a, 2014b).

Literature Review

Brief Review on Learning

There are three core concepts in the Social Learning Theory of Bandura (1977). The first concept is that people learn by observation or modelling. The second concept states that internal personal mental states are important to learning. It is not only the external environment that plays a role, but personal satisfaction or a sense of accomplishment also positively influences learning. The emphasis on internal mental states relates Bandura's theory to cognitive theories. Bandura's third core concept is that learning does not always have to produce a permanent change in behaviour (Yeoh, 2014a, 2014b, 2015b). The study employs the first core concept that human behaviour is mainly learned through modelling. Therefore in the case of this study, it is the process in which the students observed how the teacher drew the diagram of DNA replication, while softly singing the musical mnemonics. By this observation, the students would get an idea of how new behaviours are performed. This coded information functions as a guide for the subsequent action of drawing a labelled sketch of DNA replication and describing or explaining the process.

The researcher realised that the students' intrinsic mental states need to be conducive for learning, as stated in Bandura's (1977) second concept. Students need to actively assimilate the information in the lyrics of the musical mnemonics, and experience personal satisfaction that the mnemonics was able to enable them recall the mechanism of DNA replication (including the unwinding of parental DNA, parental strand acting as template, synthesis of RNA primer, DNA the joining up of nucleotides to the exposed bases by specific base pairing, formation of leading and lagging strands, as well as the direction of strand formation from 5' to 3'); and the major enzymes and proteins involved (Reece et al., 2011; Matriculation Division, 2012). Active student learning will lead to constructivism links being forged between new information (DNA replication) and existing knowledge by the student, and musical mnemonics could provide auditory cues to link this new information (DNA replication) with the song using the melody of "Twinkle, twinkle little star" that was already familiar to the respondents (Mastropieri, Sweda, & Scruggs, 2000; Yeoh, 2014a, 2014b).

Brief Review on Mnemonics

Mnemonics may be defined as devices that facilitate students' recall of information. Mnemonics effectively perform this role by linking the new, unfamiliar information with information, knowledge or experience that is already within the repository of the learner, with the use of visual and auditory cues (Mastropieri et al., 2000). Studies showed that teenage learners found that mnemonic strategies like acrostics and acronyms facilitated their recall of information by making new information more familiar, meaningful and more concrete (Bakken & Simpson, 2011, Yeoh, 2014b). Acrostics and acronyms are effective for the students to recall information on a wide range of subjects. Literature revealed that young adult learners used mnemonics to improve their vocabulary (Bakken & Simpson, 2011); and recall of selected biological pathways (Yeoh, 2015a, 2015b).

Shmidman and Ehri (2010) showed that mnemonics expedited the learning of foreign alphabets among English-speaking preschoolers (N = 36, 2 years). They found that embedded mnemonics were mastered more quickly, and suggested that the use of mnemonics reduced confusion and accelerated learning besides enhancing long-term retention among these pre-school children (Shmidman & Ehri, 2010).

Carlson, Kincaid, Lance and Hodgson (1976) found that 38 experimental subjects using the method of loci, a mnemonic, performed better than 38 control subjects who were not specifically asked to use any method of recall. When tested the experimental group had a mean recall of 60.0 as compared to the control group with 49.5 of a total of 80 names of places (nouns). The authors used a Newman Keuls post hoc test and showed that this difference was significant at $p = .01$, implying that the method of loci was an effective mnemonic. However, at an unannounced re-test given the next day, the experimental subjects had a mean recall score of 12.7 as compared to 14.9 among control subjects. The control subjects revealed in a questionnaire that they had spontaneously used mnemonics. Four types of mnemonics were used by 15 out of 38 control subjects: loci, peg word, first letter, and a story to incorporate words that needed to be recalled. Among the control subjects, those who spontaneously used mnemonics had better recall at the test (experimental group as compared to control group with 56.9 versus 42.7), and better recall at the re-test (experimental group as compared to control group with18.7 versus 10.5). A t-test showed that the difference was significant at the test, $t (36) = 4.54$, $p = .01$ and also at the re-test, $t (36) = 2.78$, $p = .01$. The mean GPA available for 12 control subjects who used mnemonics was 2.80, and the mean GPA for 21 control subjects that did not use mnemonics was 2.37. A t-test showed that the difference in GPA was significant, $t (31) = 1.82$, $p = .05$. This study showed that mnemonics facilitated recall, and that academically better students had spontaneously used mnemonics when no specific instructions were provided (Carlson et al., 1976).

A study where first letter mnemonics did not improve recall was documented in Morris and Cook (1978). In their first experiment, the mnemonics generated by experimenter and subjects did not improve recall among 30 undergraduates. The hypothesis suggested for this failure was that unrelated words were used as learning material. This has been taken into consideration by the present researchers; and it has been discussed in previous papers that one criterion for effective mnemonics was their brevity, and so unnecessary words were not included in the musical mnemonics (Morris & Cook, 1978; Yeoh, 2012, 2015a, 2015b). However, in a second experiment, Morris and Cook (1978) showed that first letter mnemonics improved recall among 36 undergraduates when they had to recall a random ordering of the days of the week. This meant that when the items were already known but the ordering of items was a problem, first letter mnemonics helped to aid retrieval.

Use of Mnemonics in Science and Biology Education

Garcia and Herrera (2012) conducted a study to investigate if mnemonics could assist fifth-grade students in learning science terminology more effectively than traditional-study methods. Garcia and Herrera (2012) wanted to determine whether fifth-graders are able to learn a mnemonic (such as method of loci, pegword, and keyword) and then use it to understand science vocabulary. Their next question was whether the same students were able to remember the science terms when tested after a period of three years (at 8^{th} grade) or five years (at 10^{th} grade). That study compared fifth-grade students' use of mnemonic techniques to traditional study methods. The objective was to determine which method was more useful in acquiring and recalling science vocabulary. The results indicated that all mnemonic techniques and the traditional study method were equally effective. It also showed that mnemonics may be a useful

tool not only in the initial learning, but also in the long-term memory of the learned material. Garcia and Herrera (2012) concluded that if primary school teachers were versatile in the use of mnemonic techniques, there may be a significant improvement in the learning of science information and its recall over the span of three years or five years (Garcia & Herrera, 2012).

Zheng (2015) found that mnemonics were helpful to facilitate second–year undergraduate students in recalling the structures and the names of aldohexoses. Aldohexoses are mentioned in the matriculation syllabus and the structures are shown, but matriculation students are not yet required to draw their structures. However the many studies reviewed showed that mnemonics are helpful for students' recall of various subjects, among students of various countries; and that the problem of memory recall among students is certainly not confined to Malaysian matriculation students.

In biology education, Stagg and Donkin (2015) proposed that mnemonics which link a species name with morphological characteristics are a complementary learning tool for promoting species memorization. Two experiments were conducted. In the first, 64 adults in a group-learning environment were taught species identification of plants using mnemonics, an educational card game and a text-based dichotomous key. In the second experiment, 43 adults in a self-directed learning environment were taught species identification using mnemonics and a pictorial dichotomous key. In both experiments, mnemonics produced the highest retention rates of species identification based on vegetative characters. Respondents enjoyed their learning using mnemonics, as did the matriculation students of this study. The researcher discussed the educational value of their findings for vegetative plant identification and broader applications in biology education (Stagg & Donkin, 2015).

Use of Musical Mnemonics in Medicine and Biology Education

In the present investigation, the use of musical mnemonics by the researcher to teach Biology is parallel to Cirigliano (2013) on the use of musical mnemonics as a learning tool in medicine and health science. Biology is a basic secondary school science for Medical Studies, that comprises Anatomy, Biochemistry pathways, Surgery, Pharmacology, Clinical procedure, Diagnostics, Medication and Treatment. Being a field that is notorious for 'brutal tests' in memorization (Cirigliano, 2013), it is not a surprise that Medicine has a history of mnemonics composed by students and instructors. Medical students needed the memory aids, as evidenced by the many mnemonics, including musical mnemonics that were available on online databases such as http://www.medicalmnemonics.com. Anatomy mnemonics and Pharmacology mnemonics were accessible at Doctors Hangout (2015). Cirigliano (2013) showed that educators or teachers played an active role in using musical mnemonics from a survey of ten musical mnemonics on YouTube (Yeoh, 2014a; Yeoh, 2014b). The musical mnemonics created for Biology students of various cohorts in this college were created by the teacher, although students had been encouraged to create their own mnemonics (Yeoh, 2013a; 2014a; 2014b; 2015a; 2015b).

Related to the use of music, Schellenberg (2006) showed that the duration of formal music lessons received by children (6 – 11 years, N = 147) correlated positively with their intelligence quotient as well as with their academic ability, and that these associations were small but long lasting. Further research in neuroscience has shown that musical training positively affects brain development; and benefits of musical training in childhood last through adulthood. It is observed that learning to play a musical instrument like a violin, flute or piano positively influences IQ and academic performance (Miendlarzewska & Trost, 2014). Besides this, Thaut, Peterson and McIntosh (2005) suggested that musical learning accesses compensatory

pathways for memory functions, through the stronger synchronization of neuron assemblies underlying verbal learning and memory. They concluded that melodic-rhythmic templates in music may drive internal rhythm formation in recurrent cortical networks involved in learning and memory (Thaut et al., 2005). This may provide a hint as to why musical mnemonics are valuable for memory recall of complex biological processes (Yeoh, 2012; 2013a; 2015a; 2015b).

The students involved in this present research have had a lecture on DNA replication, and they have also had a tutorial session in answering structured and essay questions. They reported that they understood the process (the "big picture"), but they just could not remember the details. With the musical mnemonics used for DNA replication, the students admitted that they enjoyed the biology lesson and had expressed confidence that they would be able to describe the process of DNA replication. This shows that the brief song, without unnecessary words, had enhanced their recall potential, and was an effective learning tool (Cirigliano, 2013; Morris & Cook, 1978; Yeoh, 2012, 2013a, 2015a, 2015b).

Limitations of Mnemonic Strategies

Despite the various benefits as aforementioned, it is necessary to emphasize the limitations of mnemonic strategies. Mnemonics are useful only for efficient retrieval or recall of information, but they are not comprehension strategies (Bakken & Simpson, 2011); mnemonics only facilitate the recall of new knowledge (Yeoh, 2014b), and many more limitations. Hence educators should take this into consideration to avoid promoting rote learning indirectly.

Methodology

The researcher used a simple quantitative experimental design with two conditions: an experimental group that were taught the musical mnemonics for DNA replication and a control group that studied in a traditional manner from notes and books, without using the mnemonics. Then the test performance of students in the two conditions was compared.

Details of Innovation

To enable student's recall of DNA replication in English, there searcher used musical mnemonics, a simple song set to the familiar tune of "Twinkle, twinkle little star". Each stanza*of the song has six lines and some repetition was used to obtain a musical cadence:

*Helicase enzyme unwinds the DNA,
DNA gyrase relieves the strain,
SSBP prevents recoiling,
Until replication is done,
SSBP prevents recoiling,
Until replication is done
*DNA replication takes place
In five prime to three prime (5'-3'),
On the leading strand,
Towards replication fork,
DNA replication takes place
In five prime to three prime (5'-3')
*Primase synthesized RNA primer,
DNA Polymerase III adds
Nucleotides one by one

To the primer, on the leading strand,
Nucleotides are added one by one,
In five prime to three prime (5'-3') (Refer the following Figure 1)

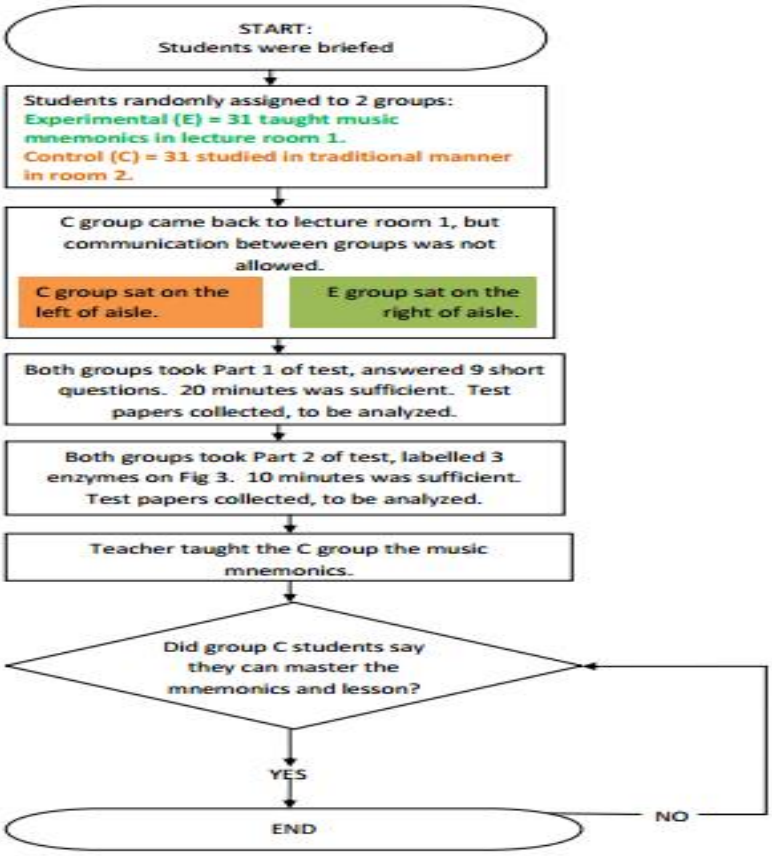

Figure 1. Flowchart showing procedures in data collection.

*DNA replication takes place
In five prime to three prime (5'-3')
On the lagging strand,
Away from replication fork,
DNA replication takes place
In five prime to three prime (5'-3')
*Primase synthesized primers,
Okazaki fragments are added,
To the primers, on the lagging strand;
Then Uracil replaces Thymine,
DNA polymerase I does this;
And ligase seals Okazaki gaps.

Respondents

The teacher met the target group of 62 students, at a late evening class on Monday, September 1, 2014 (week 12 of semester). All the students had had lectures on Expression of Biological Information, including DNA replication, since the ninth week, and had done tutorial exercises during week 10. Consent for the research activity was requested and granted by the Director of the college through email, and the respondents signed their consent on a hardcopy.

Procedures in Data Collection

The teacher explained to the students what would be done. They would be randomly assigned to control and experimental groups. The control group would go to the next room and study the processes of DNA replication from their books and notes for 30 minutes in a conventional manner. At the same time, the teacher would teach the experimental group the mnemonics and show them how to draw and label a diagram from the information in the mnemonics. Then, they should take a short test. When it was finished, the teacher would teach the mnemonics to the control group. (Figure 1 is a simple flowchart showing these procedures involved in data collection.)

The students were randomly assigned to the two groups so that the control group and the experimental group had equal number of students, 31 each. Each student picked up a folded piece of paper. If a "C" is received, he/she should be assigned to the control group, while the selection of an "E" would put him/her into the experimental group. The control group went to the next empty room and learned the processes of DNA replication in a conventional manner. At the same time, the teacher instructed the experimental group to move to the right side of the aisle, taught them the musical mnemonics; and showed them on the interactive electronic equipment (IEE) scanner how to employ the tune to draw and label the diagram of DNA replication *(*Figure 2). The group had the opportunity to observe how the teacher was able to draw Figure 2, using information in the mnemonics (Bandura, 1977). This teaching activity took 30 minutes, and the students sang the song five times.

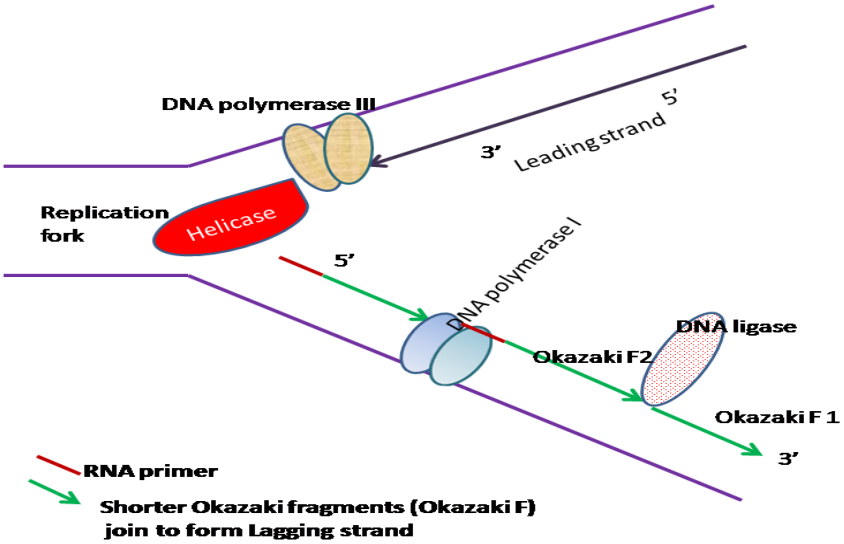

Figure 2. DNA replication.

After that, the control group was called back to the lecture room and took their seats on the left side of the aisle. There was no communication between both groups. All the students took part in a short test. The test took 30 minutes in all. For the first part of this test, students were required to answer 9 short questions. When this was done in about 20 minutes, Part 1 was collected, and Part 2 (Figure 3) was distributed. Students had to label three enzymes involved in DNA replication (Figure 3). Answering the short questions in Part 1 and labelling the enzymes in Part 2 would show whether they could recall the facts of DNA replication, and if the musical mnemonics had any influence on this memory recall of the experimental group.

When all the test papers had been collected, the teacher proceeded to teach the control group the musical mnemonics and showed them how to use it to draw and label the diagram on DNA replication. The experimental group sat quietly and listened attentively. When the control group declared that they had mastered the learning material, the teacher instructed all the students to sing together, explained the research to them, and thanked them for their contribution.

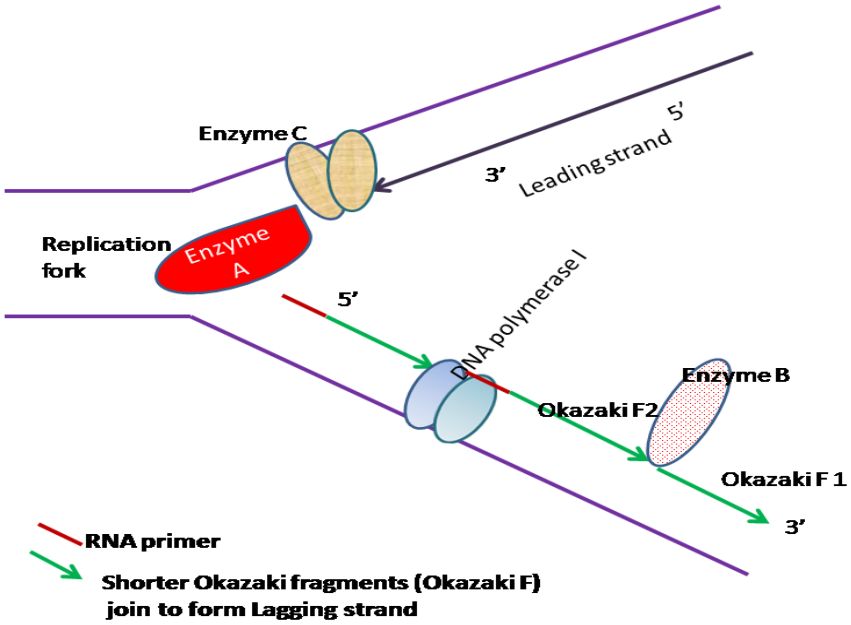

Figure 3. Naming of selected enzymes in DNA replication.

The data was analysed for both groups. All statistical analyses were carried out using SPSS, and to facilitate further research, a video CD of the mnemonics was created using Windows Movie Maker. The evaluation of the students' recall of DNA replication was done using the nine brief questions below (Part 1) and their ability to label three enzymes in Figure 3 (Part 2).

Part 1: Answer the following nine brief questions.

1. What enzyme unwinds the DNA?
2. What enzyme relieves the strain?
3. What prevents recoiling of the DNA?
4. On the leading strand, in what direction does replication occur?
5. What enzyme synthesizes the RNA primer?
6. How many primers are needed on the leading strand?
7. On the lagging strand, in what direction does replication occur?
8. What is added to the primers?
9. What replaces Uracil with Thymine?

Part 2: Label the enzymes A, B and C, on the diagram of DNA replication (Figure 3).

Results and Discussions

The results showed that the minimum score for the control group was 1, and the maximum was 7 of 12 (total score). As for the experimental group, the minimum score was 4 and the maximum was 12. The means, medians and standard deviation (SD) of the control and experimental groups were 4.10, 4.00, (1.578) and 8.23, 8.00, (2.362) respectively as summarized in Table 1. Generally, students of the control group were able to answer correctly the first two questions. The control group remembered the beginning of DNA replication better. But the experimental group was more consistent, better able to answer about 8 questions correctly. A relevant detail was that no one wrote the song, but had just used it as a tool for recall.

Table 1
Results of T-test on the Effect of Using Music Mnemonics of DNA Replication

Marks of Quiz	Learning method	N	Mean	SD	t	2-tailed p
Experimental Group	With musical mnemonics	31	8.23	2.362	8.092	.0005
Control Group	Without musical mnemonics	31	4.10	1.578		

The scores of the control group were normally distributed (Shapiro-Wilk statistic = .956, p = .234) and the scores of experimental group were also normally distributed (Shapiro-Wilk statistic = .935, p = .059). Levene's test showed that equality of variances could not be assumed (F = 7.116; p = .010). A t-test showed that the difference of 4.129 in mean scores between the control and experimental groups was significant, t (52.328) = 8.092, p= .0005. (The value of t was the same, even if equal variances could be assumed.)

A Mann-Whitney test was carried out to calculate the effect size. The effect size was found to be moderately large at 0.724, when compared to the effects of other mnemonics that have been documented (Yeoh, 2013c). However, there was an even larger effect size in other musical mnemonics research, at 0.9133 (Yeoh, 2014a), and 0.9135 (Yeoh, 2014b).

The results summarized in Table 1 showed that musical mnemonics were effective to enable students to remember DNA replication. Even though the respondents in this study were physically normal (Bakken & Simpson, 2011; Cirigliano, 2013), not impaired by multiple sclerosis (Thaut et al., 2005), they had a handicap, in that English is not their mother tongue. However, musical mnemonics had facilitated their recall of DNA replication. The results are also in line with the studies concerning students' ability to remember other biological pathways, including the Calvin Cycle (Yeoh, 2013a), Glycolysis (Yeoh, 2013b, 2014c), Electron Transport Chain (Yeoh, 2013c), Transcription of RNA (Yeoh, 2014a).

The study is in line with the Social Learning Theory of Bandura (1977). The first core concept is that people learn by observation or modelling. In this research, the teacher was the live model performing the behaviours of drawing and labelling the diagram of DNA replication and that was first observed only by the experimental group. The students were active information processors and observational learning could not occur unless their cognitive processes were at work. The experimental group was able to label Figure 3 better than the experimental group, and 25 of 31 students labelled all the 3 enzymes correctly, while in the control group only 3

students of 31 labelled the 3 enzymes correctly, and the majority of control group students could only manage to get one enzyme correctly labelled.

The second core concept of Bandura (1977) is that internal personal mental states are important to learning; this personal satisfaction or a sense of accomplishment influences learning and behaviour. In this study, the experimental group displayed cheerfulness and confidence while taking the test, and completed the test more quickly, while the control group students displayed more anxiety, took a longer time and showed reluctance to submit the test paper. When the papers were collected, and the control group was taught the mnemonics as well as shown how to draw the diagram, their anxiety was replaced with a happier countenance. In the final examination of the semester, DNA replication was one of the structured questions, and students sent messages of appreciation that the mnemonics facilitated their recall, and that they enjoyed their mnemonics classes.

Bandura's third concept is that learning does not necessarily produce a permanent change in behaviour (Bandura, 1977; Yeoh, 2014a; 2014b). Would students independently compose and use mnemonics to study biological processes? It was not always so. Although several cohorts of students were taught musical mnemonics that enabled them to learn biological processes more efficiently, and recall their learning, not every cohort of students proceeded to compose their own mnemonics. Thus, the researcher observed that this study agrees with the aforementioned three core concepts of Bandura (1977). However, only one group of students of the 2012-2013 cohort composed musical mnemonics at the instruction of the teacher (Yeoh, 2013d), and it was interesting that many students of that class obtained good GPAs and proceeded to medical and pharmacy courses in universities. This is somewhat related with Carlson et al. (1976), where students with better GPAs spontaneously used mnemonics; although in this case, the better students were more willing to compose musical mnemonics.

The study extends the theory or philosophical framework of constructivism that learners construct new knowledge out of their experiences. For learning to occur, there must be links between the new information and previous existing knowledge. The musical mnemonics used the familiar song 'Twinkle, twinkle little star', that may be considered a piece of familiar existing knowledge; and the new knowledge that needed to be accommodated was DNA replication. Musical mnemonics had combined visual and auditory stimuli (Mastropieri et al., 2000), a multisensory experience (Petty, 2009); musical mnemonics probably forged stronger constructivism links between new and existing knowledge in the respondents, and this is an extension of the constructivist learning theory.

Conclusions and Recommendations

The findings are in line with previous studies employing mnemonics to facilitate memory recall. Based on the findings, the researcher suggests that musical mnemonics should be used to facilitate recall of other biological processes including the *lac* operon (lactose operon). This will help reduce the study stress and mental exhaustion of students. Several cohorts of Matriculation students had written many appreciative comments on how they enjoyed the musical mnemonics, and how effectively musical mnemonics had reduced their confusion.

The researcher proposes that students should be encouraged to write their own mnemonics. By so doing, we will encourage our students to be independent, creative and innovative. These qualities are necessary for our students to compete in this global era. With the use of the video CD on DNA replication, it means that the teacher does not have to sing the mnemonics several

times, in order to teach the students. A precaution which the researcher continue to emphasize is that mnemonics should be as brief as possible and exclude unnecessary words (Morris & Cook, 1978; Yeoh, 2012, 2014a, 2014b, 2015c).

This research has provided more insights to the researcher in her practice of research methodology, and this had afforded personal satisfaction (Bandura, 1977). Previously, a paired samples t-test that lacked a control group was used to investigate the effects of musical mnemonics on the learning of Krebs cycle (Yeoh, 2012). Then, an independent samples t-test in the research on the Calvin cycle (Yeoh, 2013a), Glycolysis (Yeoh, 2013b), Electron Transport Chain (Yeoh, 2013c, 2015a), and Light-dependent reactions of Photosynthesis (Yeoh, 2015b) where either the data were normally distributed, or the variances were equal, and the control and experimental groups were the same size. In the research on musical mnemonics to facilitate learning of Transcription of RNA (Yeoh, 2014a), non-parametric statistics were used, because the data were not normally distributed and equality of variances could not be assumed, although the group sizes were equal. However, in the present study, the scores of both the control group and experimental group were normally distributed. Both groups were the same size, so a t-test was used to test the means, and the Mann Whitney test was performed to calculate the effect size.

The results of this study imply that DNA replication, a biological process, requiring procedural knowledge, can be successfully learned in English. It can be learned in an environment where the mother tongue is not English, and students had learned Biology in the mother tongue in school. It implies that musical mnemonics are a useful cognitive tool to facilitate memory recall for students, in an environment where Biology is taught and tested in English, the second language; to prepare students for university education where the "lingua franca" is English.

The author noted that the change in the education policy from ETeMS introduced in 2003 to MBMMBI (since 2012) had reduced the time of formal classroom communication and interaction in English. For science stream students, Maths, Additional Maths, Physics, Chemistry and Biology had been taught in English under the PPSMI education policy. Several lecturers in this matriculation college had mentally prepared themselves to face and overcome problems in teaching students who had less practice and less ease in using English. There must be innovative ways to tackle learning problems in learning and recalling Biology, and the research shows that musical mnemonics is a helpful device. Being a multi-sensory experience, musical mnemonics apply other routes to link new information with existing knowledge, so that the students recall better with mnemonics than with traditional learning. Besides that, mnemonics appeal to the humour and feelings of the students.

In summary, the results indicated that learning DNA replication with the use of musical mnemonics was more effective than traditional studying of this biological process, without mnemonics. This study shows that instruction of a biological process using musical mnemonics, a multi-sensory experience that students enjoy, facilitated constructivism and memory recall, and may lead to a significant improvement in the learning of biological sciences by college students.

Acknowledgements

The researcher is thankful to ResearchGate, where research collaborations are formed, and to friends in ResearchGate, especially Prof. Dr. Enzo Ierardi who read through the drafts of this study and provided valuable insights. Other friends who provided moral support and literature

for review included Prof. Ljubomir Jacic, Prof. Raoof Mostafazadeh, Prof. Nageswara Rao Posinasetti, Prof. Patrick Low, and Prof. Lijo Francis.

References

Alwis, C. D. (2005). *Attitude of Form Two students toward learning Science in English: A case study of schools in Kota Samarahan*. Proceedings of Seminar Penyelidikan Pendidikan Maktab Perguruan Batu Lintang, 15-16 September 2005.

Azmi, M. N., & Maniam, M. (2013). Failure of ETeMS: The Teaching Courseware Factor? *The Malaysian Online Journal of Educational Science, 1*(4), 30-37.

Bakken, J., & Simpson, C. (2011). Mnemonic Strategies: Success for the Young-Adult Learner. *The Journal of Human Resource and Adult Learning, 7*(2), 79-85. Retrieved, 2015-01-30, from http://www.hraljournal.com/Page/9%20Cynthia%20G.%20Simpson.pdf

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

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

Carlson, R. F., Kincaid, J. P., Lance, S., & Hodgson, T. (1976). Spontaneous use of mnemonics and grade point average. *Journal of Psychology, 92*, 117-122.

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

Doctors Hangout. (2015). *A Professional Networking Site for Doctors & Medical Students Worldwide*. Retrieved November 15, 2015, from http://www.doctorshangout.com

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

Garcia, J. O., & Herrera, A. J. (2012). Memorization techniques: Using mnemonics to learn fifth grade science terms. In *National Social Science Proceedings* (Vol. 49#1, pp. 55-78). Retrieved 2015-09-26 from http://www.nssa.us/journals/pdf/NSS_Proceedings_2012_Las_Vegas_1.pdf#page=58

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

Miendlarzewska, E., & Trost, W. (2014). How musical training affects cognitive development: rhythm, reward and other modulating variables. *Frontiers in Neuroscience, 7*, 1-18. doi:10.3389/fnins.2013.00279

Morris, P. E., & Cook, N. (1978). When do first letter mnemonics aid recall? *British Journal of Educational Psychology, 48*, 22-28. doi: 10.1111/j.2044-8279.1978.tb02366.x

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

Prophet, B., & Dow, P. (1994). Mother tongue language and concept development in science: A Botswana case study. *Language, Culture and Curriculum, 7*(3), 205-216. doi: 10.1080/07908319409525178

Reece, J., Urry, L., Cain, M., Wasserman, S., Minorsky, P., & Jackson, R. (2011). *Biology* (9th ed.). California: Pearson Benjamin Cummings.

Schellenberg, G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology*, *98(*2), 457-468.

Shmidman, A., & Ehri, L. (2010). Embedded picture mnemonics to learn letters. *Scientific Studies of Reading, 14*(2), 159-182. doi: 10.1080/10888430903117492

Stagg, B. C., & Donkin, M. E. (2015). Mnemonics are an effective tool for adult beginners learning plant identification. *Journal of Biological Education*, 2. doi: 10.1080/00219266.2014.1000360. Retrieved September 26, 2015, from https://www.researchgate.net/publication/276398935_Mnemonics_are_an_Effective_Tool_for_Adult_Beginners_Learning_Plant_Identification?ev=prf_pub

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/16597771

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

Yeoh, M. P. (2013a). *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, 22-24 October 2013, Le Grandeur Hotel, Senai, Johore Baru, Malaysia.

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

Yeoh, M. P. (2013c). *Musical Mnemonics to Facilitate the Learning of Matriculation Biology: Electron Transport Chain*. Paper presented at 5thCoSMed International Convention, 11-14 Nov 2013; 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. Retrieved from http://www.recsam.edu.my/index.php/resources/learning-science-and-mathematics

Yeoh, M. P. (2014a). Musical Mnemonics to Facilitate Learning of Transcription of RNA. *Learning Science and Mathematics, 9,* 24-34. Retrieved from http://www.recsam.edu.my/index.php/resources/learning-science-and-mathematics

Yeoh, M. P. (2014b). Musical Mnemonics to Facilitate Learning of Protein Synthesis: Translation. *Sainsab, Journal of the Association of Science and Mathematics Education Penang, 17,* 1-11. Retrieved from http://www.sainsab.org/

Yeoh, M. P. (2014c). Musical Mnemonics to Facilitate the Learning of Matriculation Biology: Glycolysis. In J. Leach, Nur Jahan Ahmad & Suhaidah Tahir (Eds.), *Learning Science and Mathematics in the Classroom: Case Studies of Successful Practices* (pp. 97 – 106). Penang: SEAMEO RECSAM.

Yeoh, M. P. (2015a). Musical Mnemonics to Facilitate the Learning of Matriculation Biology: Electron Transport Chain. In Devadason Robert Peter, Zurida Ismail& Ng Khar Thoe (Eds.), *Empowering the future generation through science education* (pp. 91 – 101). Penang: Southeast Asian Ministers of Education Organization, Regional Center for Education in Science and Mathematics. doi: 10.13140/RG.2.1.3157.9688

Yeoh, M. P. (2015b). Musical Mnemonics to Facilitate Learning of Matriculation Biology: Light-dependent Reactions of Photosynthesis. *Pertanika Journal of Social Science and Humanities, 23*(2), 375-389.

Yeoh, M. P. (2015c). *DNA replication (video recording of musical mnemonics).* Retrieved from https://www.researchgate.net/publication/283902016_DNA_replication_%28video_recording_of_musical_mnemonics%29

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

Zheng, S. (2015). Mnemonics for the Aldohexoses that Aid in Learning Structures, Names, and Interconversion of Fischer Projection Formulas and Pyranose Chair Forms. *Journal of Chemical Education, 92*(2), 395-398. doi: 10.1021/ed500254x