

MUSICAL MNEMONICS TO FACILITATE THE LEARNING OF THE KREBS CYCLE

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Abstract

This paper reports a second occasion of using music mnemonics to facilitate students' learning. It has an added aim of improving the research design that was used by the researcher in 2012. Learning Biology requires students to master declarative knowledge and procedural knowledge. English is the medium of instruction in the matriculation college but it is not their first language. Hence, the students found it difficult to recall the Krebs cycle in English. With the use of musical mnemonics, students in the experimental group were enabled to remember the processes involved in the Krebs cycle correctly, in English, $t(60) = 11.581$, $p = .0005$. From this experimental result, the researcher posits that musical mnemonics are a useful tool to facilitate recall of this and other biological pathways, and also a tool to stimulate student interest in learning science during adolescent years. The author suggested the criteria for musical mnemonics to be effectively used to trigger memory recall of biochemical processes that require procedural knowledge. To facilitate research and the sharing of resources, a video recording of the music mnemonics was uploaded on the researcher's contribution pages on ResearchGate, a networking site for researchers and scientists.

Keywords: Krebs cycle; Tricarboxylic acid cycle; Musical mnemonics; ETeMS education policy in Malaysia

Introduction

This paper reports a second occasion of using music mnemonics to facilitate students in learning the Krebs cycle. It has an added aim of improving the research design that was used in Yeoh (2012). The respondents are the most recent cohort of students in the college.

Background and Overview

Our existing knowledge is encoded in our brain as 'constructs'. New information needs to be connected to existing concepts, knowledge and experience to be understood. The linking process is 'constructivism'. Constructivism links are stronger if they involve recent vivid engrossing, multisensory experiences within the learning process (Petty, 2009). In this study, musical mnemonics is the learning device to engage the students with songs that are stimuli on sight and hearing senses, and may be regarded as multisensory, so as to trigger their recall of the Krebs cycle (Cirigliano, 2013; Schellenberg, 2004, 2005, 2006).

A second fact about learning is that mastering facts is different from mastering procedural knowledge (Michael, 2006). Learning the Krebs cycle requires the students to remember the facts; besides that, they must present the facts in the correct order, in English. The correct

sequence of reactions must be maintained. Thus, it is harder for students to master biochemical or biological processes that require both correct facts and a correct sequence of presenting the facts (Yeoh, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e). This problem is not encountered when they study topics like ‘Molecules of Life’ or ‘Biodiversity’ that mainly require declarative knowledge.

A third aspect is that learning often takes place in social settings, or that we learn through observing and imitating significant others. This is termed ‘modelling’ by Bandura (1977) in his Social Learning Theory (Yeoh, 2012, 2013a, 2013b, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e).

Rationales and Purposes

Matriculation students learn Biology in English, as is required by the education policy “English in Teaching Mathematics and Science” (ETeMS or sometimes referred to as PPSMI, its Malay acronym). However, nearly all the students are from homes where Malay, Chinese or Tamil are their respective mother tongue and the preferred language. Students have learned English for about ten years in school, but they admit that they are not versatile enough to think in English and do not possess a command of English equivalent to their ability in their first language. Students admitted that although they understood the Krebs cycle, they had problems to remember the names of the metabolites that they had learned for the first time. Everything was unfamiliar to them. They had to put in effort to get the spellings correct. Besides the Krebs cycle was just one subtopic in the chapter on cellular respiration, although it was an interesting significant sub-topic; and they wondered if they should be putting so much effort in just one subtopic. The students actually revealed that they were mainly extrinsically motivated by grades, rather than by intrinsic motivation, a passionate interest in science as well as a realization of the value of studying science to be a scientifically literate individual in a society that progresses through advances in science and technology (Yeoh & Ierardi, 2015).

Students needed to master procedural knowledge. The review of literature had shown that mnemonics were useful in facilitating recall among respondents of various age groups (Bakken & Simpson, 2011; Cirigliano, 2013; Yeoh, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e). This research to use music mnemonics for the learning of Krebs cycle was necessary because Krebs cycle is a challenging topic. The syllabus required students to be able to describe the sequence of metabolites from Oxaloacetate to Citrate, Isocitrate, α -Ketoglutarate, Succinyl CoA, Succinate, Fumarate and Malate (Reece et al., 2011; Yeoh, 2012). They must know the steps where energy molecules: ATP, NADH and FADH are produced. Students must be able to justify the number of ATP produced for one molecule of glucose that is completely oxidized.

Students needed to recall in English. Students complained that even the names of metabolites were unfamiliar. They found it difficult to recall the long scientific names correctly, in English, a language that they seldom used. They do not think in English. Students had to build their knowledge and understanding in their mother tongue, as well as translate their understandings into English. The students had a tendency to discuss most things about their learning in the Malay language; and during these discussions among themselves, only the Biology terms or names of organic acids would be spoken in English. Being the college coordinator of ETeMS, the researcher encouraged students to converse in English whenever possible. As the ETeMS head, the researcher had been vigilant to take note of the language used by students when they spoke among themselves. To maximize the use and exposure to English, the college had declared that Tuesdays, Wednesdays and Thursdays would be “English Days” since May 2015. The researcher had another concern that is whether students had spelled the terms correctly,

because she herself had misspelled Krebs as ‘Kreb’ during schooling years before. When she heard her teacher once said ‘Krebs cycle’, it had gone into her notes as ‘Kreb cycle’. The researcher could empathize with the students; she had found Krebs cycle difficult to remember and had already used a music mnemonic to facilitate recall of this process when she was a student. At least, students did not need to remember the molecular and structural formulae of the metabolites. But students needed to describe the reactions that included decarboxylation reactions, redox reactions, and isomerisation (Reece et al., 2011; Syllabus Specifications for Biology, 2012). Since ETeMS is still currently enforced for Matriculation students (Yeoh, 2014a, 2014b, 2015e), the goal of this research is to facilitate students to recall the steps of the Krebs cycle correctly, in English. The researcher employs music mnemonics because mnemonics facilitate learning by making new information (including the names of the metabolites in the correct sequence), more familiar and concrete (Bakken & Simpson, 2011; Yeoh, 2014b, 2015d, 2015e).

The students needed a boost in motivation. Several studies have shown that the motivation of students to learn science declined during pre-adolescent years (Osborne, Simon, & Collins, 2003; Simpson & Oliver, 1990), and during adolescent years (Vedder-Weiss & Fortus, 2012). Matriculation students were no different. They had admitted a reduced motivation to learn science, not just because of their age; but also because it was difficult to learn the science terminology, and spell the terms right in English. “There is so much to learn in Biology” is one of their chief complaints. However, Jack and Lin (2014) suggested that students’ motivation to study science may be kindled by employing strategies that involved novelty and meaningfulness. The researcher hopes that the music mnemonics for Krebs cycle would be viewed as a novel strategy by the students to facilitate their recall of difficult biological pathways (Yeoh, 2012, 2015a, 2015b, 2015c, 2015d, 2015e; Yeoh & Ierardi, 2015).

Extended research to improve previous studies. A research on facilitating students’ learning of the same topic (Krebs cycle) with a previous cohort of students was carried out in 2012, but that research did not have a control group (Yeoh, 2012). The researcher had thought that it was not too fair to get students to be in the control group, even though they got into it by a clearly random process (Yeoh, 2015d, 2015e).

However, a discussion of the matter with the previous deputy director cleared the doubts of the researcher. The control group should have been given the same teaching after the data was collected, until they were satisfied that they had mastered the knowledge. Hence this study would include a control group. In that 2012 study, the standard deviation had also exceeded the mean ($4.75 > 4.12$). The researcher wanted to see if better results could be obtained in this present study using the same Krebs cycle mnemonics. The researcher had proceeded to investigate the effectiveness of music mnemonics on other biochemical pathways using a control group (Yeoh, 2013a, 2013b, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e). The purposes of this research are to enable the students to remember the Krebs cycle correctly in English; and also to improve upon the method that had been used earlier (Yeoh, 2012).

Literature Review

Brief Review on Learning

This study employs the first core concept of Bandura’s social cognitive theory (1977) that much of human behaviour is learned through modelling. The students observed the teacher, and imitated the actions or behaviours of how the words of songs were used to draw the Krebs cycle in Figure 1 (Yeoh, 2014a, 2014b, 2015a, 2015d, 2015e).

Bandura's (1977) second concept has placed importance on mental states. The students needed to be mentally alert and ready to actively assimilate the words in the mnemonics, and experience personal satisfaction that the two simple songs could enable them recall the sequence of metabolites, as well as the steps of production of ATP, NADH and FADH₂. Active learning is occurring when links are constructed between narration of the Krebs cycle processes (new info) and the melodies of the songs (pre-existing knowledge) by the student, as well as mnemonics provide auditory cues to link new information (the Krebs cycle reactions) with the simple familiar melodies (Mastropieri, Sweda, & Scruggs, 2000; Yeoh, 2014a, 2014b).

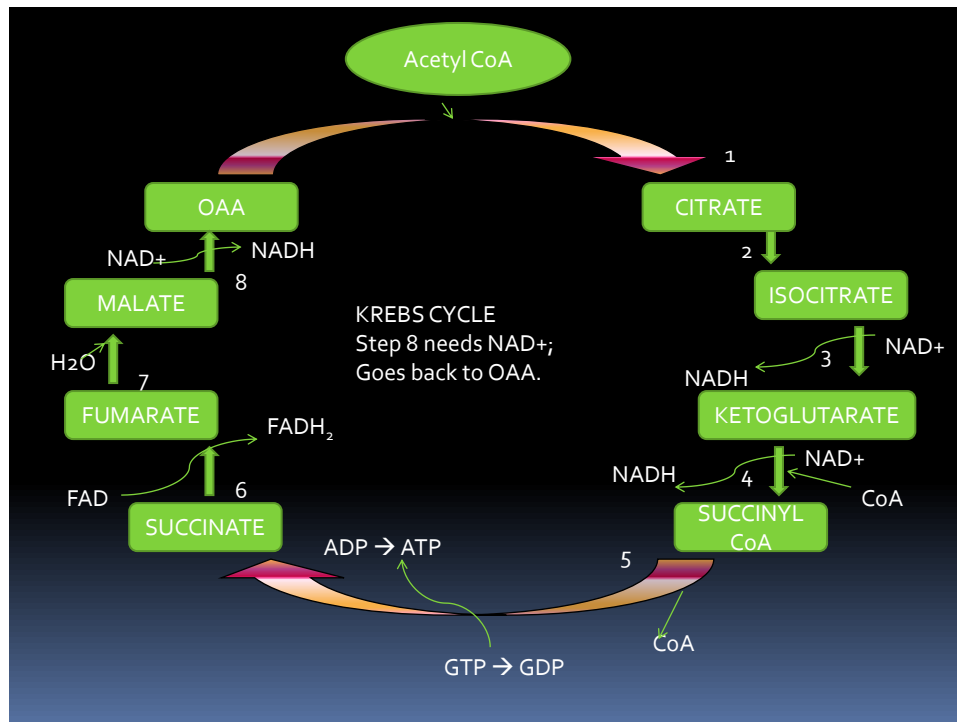


Figure 1. The Krebs cycle (drawn from info in the mnemonics).

Brief Review on Mnemonics

Mnemonics may be defined as devices that facilitate the recall of information, by using visual and auditory cues, to connect the unfamiliar information that need to be learned with the learner's pre-existing knowledge (Mastropieri et al., 2000). In a similar manner, Bakken and Simpson (2011) state that mnemonic strategies, including acrostics and acronyms, facilitated information recall of new information by presenting it in a familiar context, hence rendering the new info more familiar and concrete. Mnemonics have been effectively used by young adult students to recall information on various subjects, including vocabulary knowledge and biological pathways (Bakken & Simpson, 2011; Yeoh, 2012, 2013a, 2013b, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e). Laing (2010) who researched on accounting students agreed with the statements of Bakken and Simpson (2011).

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 that was suggested for this failure to facilitate recall was that unrelated words were used as learning material. This has been a precaution that was considered by the present researcher and discussed in her previous

papers as a criterion for effective mnemonics was their brevity, and removal of unnecessary words in her musical mnemonics (Yeoh, 2012, 2013a, 2013b, 2013c, 2014a, 2014b). 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 arrangement of days. This meant that when the items were known, but the arrangement of items was a problem, first letter mnemonics helped to overcome the problem and to aid retrieval. Here, it is stressed that mnemonics are devices for enhancing recall and not for building understanding. Mnemonics cannot replace classes that give priority to building comprehension (Yeoh, 2012, 2013a, 2013b, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e).

For this study, the same two songs were used as in the previous study (Yeoh, 2012). The first song lists the correct order of metabolites in the Krebs cycle, and was set to the tune of “Old MacDonald had a farm”. Students were familiar with this simple melody. The second song was used to recall the main reactions that occur at each of eight steps of the Krebs cycle, including the production of NADH, FADH₂ and ATP. This song used the melody of “Papa loves mama”. As in previous studies carried out by the researcher, it was the teacher who created the mnemonics and video recording for her students (Yeoh, 2012).

However, the present study may be considered a slight improvement over Yeoh (2012) because it includes a control group. An independent samples t-test or a non-parametric test would be used, depending on whether the data obtained satisfied the normality test and Levene’s test. It was found that the distribution was normal for both control and experimental groups, so a t-test was employed.

It is emphasized again that mnemonics were not used as comprehension strategies (Bakken & Simpson, 2011). The students had learned the Krebs cycle in the traditional manner through lectures and tutorials. Despite drawing the Krebs cycle several times, they still could not recall the reactions. But when they were taught to use the musical mnemonics for the Krebs cycle, the students declared that the simple familiar melodies had been able to engage their minds and the songs had enhanced their recall potential (Yeoh, 2015a, 2015d, 2015e).

Methodology

Details of Innovation

Two songs were employed by the researcher as in Yeoh (2012). The first song was a variation of “Old McDonald had a farm” and it used acrostics to recall the metabolites of the Krebs cycle in the correct order, besides the number of carbon atoms of the actual metabolite. The second song was a variation of “Papa loves mama” (Figure 2). It describes the main reactions that occur at each of the eight steps of the Krebs cycle, including the steps of production of NADH, FADH₂, and ATP (Yeoh, 2012, 2015b, 2015c).

Song 1 uses Old Mac Donald had a farm:

“Citrus, Isobel, Ketty Sing, Sulk (n) Fume (on) Male Oxen.”

Song 2 is a variation of 'Papa loves mama':

**"Step 1, it forms citrate; Step 2 isomerises it;
Step 3 needs NAD⁺; Step 4 needs NAD⁺; and CoASH;
Step 5 rids CoASH, gets ATP from GTP; Step 6 needs FAD;
Step 7 needs H₂O; Step 8 needs NAD⁺; Goes back to OAA."**

Figure 2. Lyrics of the songs (Yeoh, 2012)

Respondents

The respondents were sixty two students from the researcher's tutorial classes. After knowing these students for about three months, as well as understanding their strengths and weaknesses, the researcher was more concerned about their academic achievement. Besides that concern, one of the academic performance indices (API) in matriculation colleges was the performance of tutorial students in the final exams. So it was to the researcher's advantage if the students could understand and remember the syllabus content, including the Krebs cycle (Syllabus Specifications for Biology, 2012).

Procedures

The tutorial students had already been divided into two equal groups so that there were 31 students in the experimental and control group. In an earlier quiz on Biodiversity, the marks of the two groups did not differ significantly.

The control group used the next empty lecture hall and learned the Krebs cycle from their notes, while in the lecture theatre of the experimental group, the researcher proceeded with the research. The researcher told the experimental group to sit only on the right half of the lecture theatre. The researcher taught the musical mnemonics, showing the experimental group students on the scanner, how to employ the words of the two songs to draw and label the diagram of the Krebs cycle (Figure 1). This activity required about 30 minutes, and the researcher was able to go through the steps of the Krebs cycle three times. Then, the control group was asked to come back to the lecture theatre. They sat on the left half of the lecture theatre. Both groups were separated by the aisle, and there was no communication between the groups. Both groups did a short test (responding to the questions raised in the following Evaluation questions).

1. What is the name of the molecule that binds with oxaloacetate?
2. What is formed when that molecule binds with oxaloacetate?
3. An isomerisation reaction occurs next in the Krebs cycle, what is formed?
4. What reaction takes place when Carbon Dioxide is removed?
5. What is the 5C substance formed when Carbon Dioxide is removed?
6. To form this 5C compound, a redox reaction occurs. What is reduced?
7. A second removal of Carbon Dioxide occurs. What is formed?
8. How many C atoms are in this compound?
9. What triphosphate molecule is needed to form ATP?
10. In one turn of the Krebs cycle, how many molecules of Carbon Dioxide are removed?
11. Label the substances A to J, on the diagram of the Krebs cycle evaluation (Figure 3).

For this test, students answered ten short questions on Krebs cycle and label ten metabolites on Figure 3. Students were told to give correct spellings of the substances in Figure 3; since recalling names of metabolites was one of their chief problems. They were told that they would have half an hour for the evaluation.

After the half hour, students passed up their evaluation sheets. Then the researcher taught the musical mnemonics again, focusing attention on the control group. When the control group were affirmative that had mastered the mnemonics, the teacher had all the students to sing together. The data was analysed for both groups, using SPSS (Yeoh, 2014a, 2014b, 2014c, 2015a, 2015b, 2015c, 2015d, 2015e).

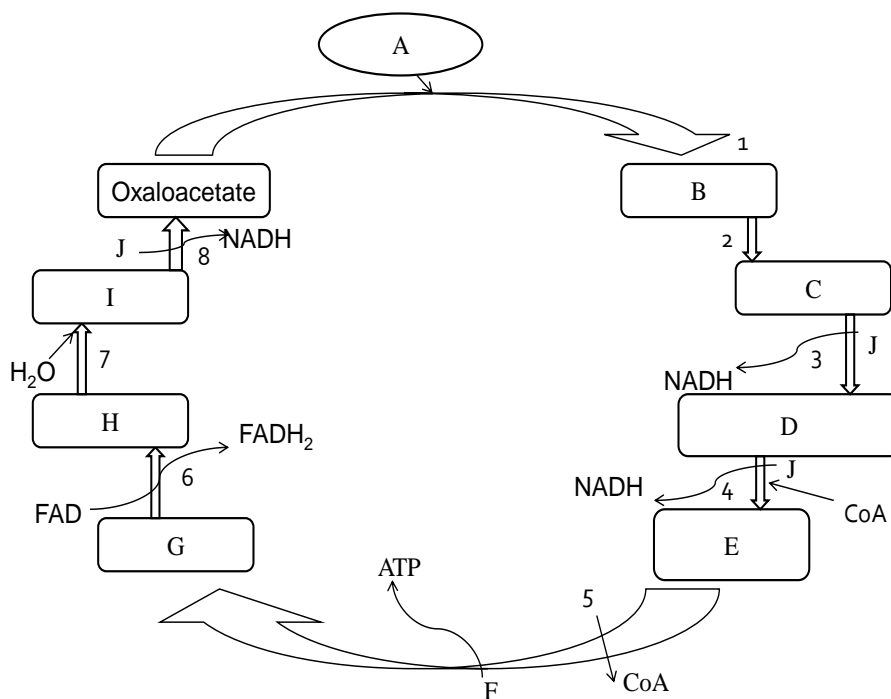


Figure 3. Evaluation of the Krebs cycle.

Results and Discussions

The results are shown on Table 1. Generally, students of the control group were not able to answer correctly Questions 3, 5, 6, 7, 8, and 10 and were able to correctly label A and B (Figure 3). It seemed that the control group students remembered the beginning of the pathway of Krebs cycle better. But the experimental group was more consistent in giving correct answers, better able to answer about eight short questions correctly and label more than six organic substances correctly in Figure 3. The researcher was glad that no one wrote the songs, but had just used it as a tool for recall. This meant that students were able to apply the knowledge, rather than just memorizing the song.

The effect size was 0.8197, and this was quite a large effect size. The results showed that musical mnemonics were effective to enable students to remember the Krebs cycle; by consolidating their memory processes. The results were in line with previous studies employing

mnemonics to facilitate memory consolidation (Yeoh 2012, 2013a, 2013b, 2013c, 2014a, 2014b, 2014c, 2015a, 2015d, 2015e).

Students also were quick to give oral feedback to the researcher on how they enjoyed the songs, especially since their school teachers had never used music mnemonics as tools for recall. This was in line with Jack and Lin (2014) who had suggested that motivation to study science can be increased by employing strategies that involved novelty and meaningfulness (Yeoh & Ierardi, 2015). To the researcher, the important thing was that the mnemonics would facilitate students to recall, but the fact that they enjoyed the lesson and felt positive and motivated came as a bonus.

Table 1

Results of t-test on the Effect of Using Music Mnemonics of the Krebs Cycle

Marks	Learning method	N	Mean	SD	t	2-tailed p
Experimental Group	With musical mnemonics	31	14.94	2.34	-11.581	.0005
Control Group	Without musical mnemonics	31	6.29	3.44		

Conclusions and Recommendations

The findings are in line with previous studies that employed mnemonics to facilitate memory recall. From these findings, the researcher posits that musical mnemonics should be used to facilitate recall of other biological processes. By doing so, we may reduce the stress and mental exhaustion that is evident on the faces of our students, especially during study week (Yeoh, 2013a, 2014c, 2015a). The researcher also has been encouraging students to write their own mnemonics, to give them room to express their creativity and innovativeness.

The research has benefited the researcher in the practice of research methodology. From not having a control group to including a control group meant that the researcher had to do some soul searching as to whether students could accept being in the control group and being at a seeming disadvantage, even when they knew it was by random chance. The researcher is thankful to the deputy director of the college who had given wise and sound counselling at the time of need. Furthermore, in this study, the researcher also did not encounter 'unusual data' as a standard deviation being larger than the mean, as was evident in Yeoh (2012).

However, in this present study, although the scores of the experimental group were higher than the control group, as well as more negatively skewed, the distribution was still normal for both the control and experimental groups, so a t-test was employed. The results of this study, and other studies on music mnemonics, imply that even biological processes can be successfully learned in English as reported by Yeoh (2012-2015).

Biological procedural knowledge can be learned by students whose first language is not English. This implies that musical mnemonics is a useful device to facilitate memory recall for students, and to facilitate students to perform well at pre-university level, as well as to boost their motivations to study science during adolescence when they faced a decline in motivation. Musical mnemonics are one of the strategies that teachers may use to present science learning

in a novel and meaningful manner to facilitate students' recall of biological processes, as well as enhance student motivation to study science in adolescent years.

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References

- 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.
- Bandura, A. (1977). *Social Learning Theory*. New York: General Learning Press.
- Cirigliano, M. (2013). Musical mnemonics in health science: A first look. *Medical Teacher*, 35(3), e1020- e1026. doi:10.3109/0142159X.2012.733042
- Jack, B. M., & Lin, H.-S. (2014). Igniting and sustaining interest among students who have grown cold toward science. *Science Education*, 98, 792–814. doi: 10.1002/sce.21119
- Laing, G. (2010). An empirical test of mnemonic 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.
- Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education*, 30, 159-167. doi:10.1152/advan.00053.2006
- Morris, P. E., & Cook, N. (1978). When do first letter mnemonics aid recall? *British Journal of Education Psychology*, 48(1), 22-28. doi: 10.1111/j.2044-8279.1978.tb02366.x
- Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079.
- Petty, G. (2009). *Evidence Based Teaching* (2nd ed.). Nelson Thornes: Cheltenham.
- Reece, J., Urry, L., Cain, M., Wasserman, S., Minorsky, P., & Jackson, R. (2011). *Biology* (9th ed.). California: Pearson Benjamin Cummings.
- Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychological Science*, 15(8), 511-514.
- Schellenberg, E. G. (2005). Music and Cognitive Abilities. *Current Directions in Psychological Science*, 14(6), 317-320.
- Schellenberg, E. G. (2006). Long-Term Positive Associations between Music Lessons and IQ. *Journal of Educational Psychology*, 98(2), 457– 468.
- Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, 74(1), 1-18.
- Vedder-Weiss, D., & Fortus, D. (2012). Adolescents' declining motivation to learn science: A follow-up study. *Journal of Research in Science Education*, 49(9), 1057-1095.
- 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, Johor 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 5th CoSMed International Convention, 11-14 Nov 2013, SEAMEO RECSAM, Penang, Malaysia.
- Yeoh, M. P. (2014a). Musical Mnemonics to Facilitate Learning of Transcription of RNA. *Learning Science and Mathematics*, 9, 24-34. Retrieved August 10, 2016, from https://www.researchgate.net/publication/270454022_Musical_Mnemonics_to_Facilitate_Learning_of_Transcription_of_RNA
- Yeoh, M. P. (2014b). Musical Mnemonics to Facilitate Learning of Protein Synthesis: Translation. *Sainsab, Journal of the Association of Science and Mathematics Education*, 17, 1-11. Retrieved August 10, 2016, from <http://www.sainsab.org/sainsab-vol-17-2014>
- 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 R. P. Devadason, I. Zurida, & K. T. Ng (Eds.), *Empowering the Future Generation through Science Education* (pp. 91 – 101). Penang: SEAMEO RECSAM.
- Yeoh, M. P. (2015b). *Lyrics of Mnemonics: Krebs cycle*. Available from https://www.researchgate.net/publication/262185471_Lyrics_of_Mnemonics_Krebs_Cycle doi: 10.13140/2.1.4421.2806
- Yeoh, M. P. (2015c). *The Krebs cycle: Video recording*. Available from https://www.researchgate.net/publication/262188581_The_Krebs_Cycle_video-recording_2
- Yeoh, M. P. (2015d). 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. (2015e). Musical mnemonics to facilitate the learning of DNA replication. *Learning Science and Mathematics*, 10, 1-16. Retrieved August 10, 2016, from https://www.researchgate.net/publication/288713688_MUSICAL_MNEMONICS_TO_FACILITATE_THE_LEARNING_OF_DNA_REPLICATION?ev=prf_pub
- Yeoh, M., & Ierardi, E. (2015). Motivation and achievement of Malaysian students in studying Matriculation Biology. *International Journal of Advanced Research*, 3(11), 966-978.