EFFECTIVENESS OF HIGHER ORDER THINKING SCAFFOLDING TOOL AS A KNOWLEDGE TRANSFER INSTRUMENT AMONG UNIVERSITY OF NAMIBIA SCIENCE STUDENTS

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Abstract

This paper presents the results of the study carried out at the University of Namibia on the extent to which high order thinking scaffolding tool can assist students to transfer knowledge. To examine the tool, a quasi-experimental design within the flipped-classroom was used in a mixed method study. Students were divided into two groups, the experimental group and the control group. These two groups were all approached in the similar manner and directed at different times of the day. The only difference was that the experimental group was provided with a scaffolding tool, while the control group had no scaffolding tool. The objective of the study was to evaluate the effectiveness of the Higher Order Thinking as a scaffolding tool that can improve students' knowledge transfer. When the means were compared, it was found that there is no statistical significant difference between the two means for the Higher Order Thinking Tool group (M= 4.89) and the control group (M= 4.27),

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which gave a p= 0.35. This suggests that the High Order Thinking scaffolding tool slightly promotes students' knowledge transfer.

Introduction

Natural Science is one of the significant branches of science that needs close attention (Lederman, 1992). In Sub-Sahara Africa there are insufficient numbers of qualified scientists, such as doctors, chemists, food scientists, biologists, engineers, geologists (Posthumus, Martin, & Chancellor, 2012). To respond to this challenge, we need to employ powerful techniques with a potential to improve science education in the country for the country to have adequate number of scientists.

Developing effective teaching and learning requires educators to design strategies that motivate students to be more engaged in their studies. The use of digital videos in education has been widely studied and employed in recent years as one of the powerful tools for the dissemination of information in education. However, effective use of videos in education was limited by several factors, such as lack of skills by educators, cost of media and other equipment, and inaccessibility and difficulties to fit these media contents pedagogically into instructions. The significant growth in technologies is a concern to many educators, and the major concern is how to engage and take full advantage of the instructional media in order to provide more effective student-centered instructions in many different ways, including online courses and a flipped classroom model of teaching (Giannakos, Chorianopoulos, & Chrisochoides, 2015).

The flipped or inverted classroom model is a pedagogical method in which the content and material are delivered primarily outside the classroom environment, using online tools and educational technologies, while in-class time is used for hands-on activities, elaboration on advance concepts, active learning through advanced problem solving, and student collaboration (Lockwood & Esselstein, 2013, Galway, Berry, & Takaro, 2015). This means class time is freed up for active student-student and student-educator collaboration, and this allows the educator to spend quality in-class time on students' interaction via advanced problems solving activities (Lockwood & Esselstein, 2013). These types of blended-learning classrooms make use of various technologies, such as digital videos, computer games, and other means of technology to scaffold learning in the classroom (McCallum, Schultz, Sellke, & Spartz, 2015).

Scaffolding can be defined as a temporary framework of poles and planks that is used to support workers and materials during construction or modification of buildings. This definition was then applied to the education context and said to be a temporary framework to support students when needed and the support will be removed when not needed. So, scaffolding can be described as a tutorial process where an adult or expert helps the less skillful person to achieve his/her goal (Lajoie, 2005).

The use of Information Communication Technologies (ICTs) in education has gained much recognition since the nineties though a number of challenging factors deterred ICT application in education. However, most of these factors were addressed during the 21st century, and this also applies to the University of Namibia (UNAM). Nevertheless, the University is still facing many challenges, such as teaching space, modernising of the lecturing approach, and a lack of infrastructure. This prompted us to look at how to improve the situation through examining the effectiveness of the Higher Order Thinking Scaffolding Tool as a Knowledge Transfer Instrument among Science Students.

The main research question was:
To what extent can the Higher Order Thinking Tool assist students in transferring knowledge to become independent thinkers?

Study Hypotheses

To test the extent to which Higher Order Thinking Tools can assist Chemistry and Biochemistry students to transfer the learned knowledge, the following hypotheses were developed and tested:

Hypothesis 1: Higher Order Thinking Tools (HOTT) can help students to become independent thinkers so enable them to transfer knowledge from the lesson to the similar problems in different concepts:
Hypothesis 2: Flipping classroom on its own may have no effect on knowledge transfer.

Literature review

Chemistry and Biochemistry lecturers use many concepts that students may find difficult to understand, and it is for this reason that students need extra support from their lecturers. To engage students in learning requires a more student-centered teaching approach than the traditional lecturer-centered approach (Bodner & Orgill, 2004; Brush & Saye, 2002).

A student-centered approach is designed to give students a chance to take an active role in their learning by taking the responsibility of organisation, knowledge construction and evaluation of content from the facilitator (Brush & Saye, 2002; Nemanich, 2009; Banks & Vera, 2009; Dennen, 2004). The idea is to foster students' engagement and involvement which, in turn, helps them to develop higher order thinking and critical problem solving skills. Brush and Saye (2002), Bliss, and others

(1996), and Wilson and Devereux (2014) emphasised that scaffolding provides the means to enable students to complete tasks and become more independent, as opposed to keeping on depending on the teachers and peers. The students are freely interacting with one another in a group, which promotes learning from peers. Choi, Land, and Turgeon (2005) posit that peer collaboration promotes sharing of a variety of information among students, justify their prospective, and attain a common understanding through collaboration.

Bliss, and other (1996) argue that for a new skill to be acquired, it must be first comprehended. Scaffolding involves keeping the tasks constant, but does not simplify. Instead, it simplifies the students' way of comprehending throughout the learning process. There are numbers of scaffolding tools that one can choose from, depending on what educators want to improve in their classes. In this study, the research focused on analogical scaffolding for fostering student retention and scaffolding for higher order thinking by using prompt cards.

Higher Order Thinking Tools (HOTT)

Critical thinking can be defined as a habit of mind characterised by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion (Binta, Andrea, & Carol, 2012, Limbach & Waugh, 2010). The ever-changing world of today requires citizens who are thinking critically. Our students need more than just building their knowedge; they need to develop their higher order thinking skills in order to be excellent problem solvers (Miri, David, & Uri, 2007). The ability to think critically is an important attribute for every person, especially in today's world with complexed issues; people must be able to make intelligent decisions and think critically. Hence, critical thinking must be the primary focus for higher education in order to provide the intellectual training for its students (Miri, et al., 2007; Binta, et al, 2012).

In order to enable transition of students' knowledge and skills, educators need to help them develop critical thinking skills. This is vital because critical thinking is required for the analysis of unfamiliar situations, for high problem solving capabilities, and for enhancing decision making capabilities (Miri, et al., 2007).

Benjamin Bloom's Taxonomy, which most researchers, teacher educators, curriculum planners, and examiners used to place objectives of education in hierarchy since 1956, demonstrates well higher order thinking (Narayanan & Adithan, 2015). The hierarchy is shown in Figure 1, which is adapted from Panvini, et al., 2015.

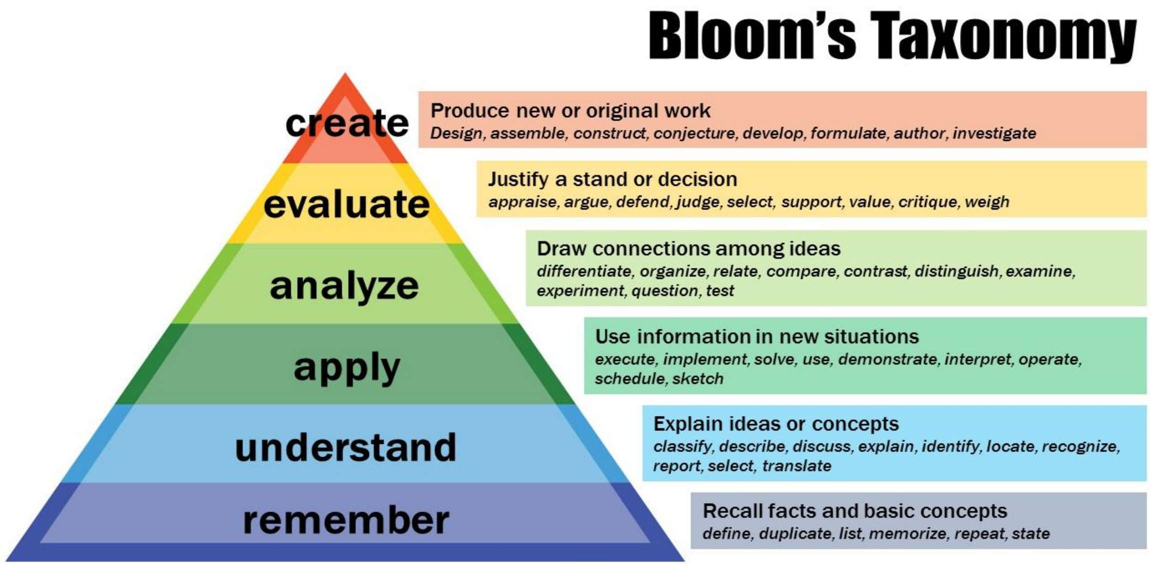


Figure 1: Bloom's Taxonomy pyramid; https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

The three levels, Knowledge (remember), Comprehension (understand) and Application (apply), are known as Lower Order Thinking Skills (LOTS), while Analysis, Synthesis (create) and Evaluation are called Higher Order Thinking Skills (HOTS) (Narayanan & Adithan, 2015).

Higher order thinking tools on Cognitive change (Transfer)

This tool works with the assumption that, when students learn, they are able to transfer what they learn from the lesson to similar problems they may encounter in their social life. HOTT can help students to transfer the knowledge from school to everyday life situations, since students will use their prior knowledge or experience to address new challenges, and this is very important, especially at the work place (Cleary, 2013). It is necessary to think about transfer and always relate it to first learning about something, and then asses the students' abilities to apply this onto a similar situation in a different context (Bransford, Brown & Cocking, 1999). This means students learn by using what they know to construct new understanding. Sometimes students may have the knowledge which is relevant to a learning situation, but is not activated during the learning process. Hence, it is the responsibility of the lecturers to activate this learning and this can be done through scaffolding, for example, by giving students some questions that require higher order thinking skills (Dixon & Brown, 2012). The most important goal of teaching is to help students to transfer what they learn in schools to everyday settings at work places, the community and elsewhere. Stephenson and Sadler-

McKnight (2016), in their study on developing higher order thinking skills, which used the Science Writing Heuristics (SWH) Method in a Chemistry laboratory with a quasi-experimental pretest-post-test design, compared the effect of SWH to the traditional experiment (TRAD) method on students' Higher Order Thinking Skills over a period of 24 weeks. The results showed that there was a significant difference between the posttest means SWH, M= 15.90, and the pretest means with M= 13.60 for TRAD), meaning that SWH students improved their critical thinking scores over their TRAD colleagues (Stephenson and Sadler-McKnight, 2016).

Miri et al., (2007) conducted another study, assessing the effects of purposive teaching methods (case study) using two Critical Thinking CT tests, the California Critical Thinking Disposition Inventory Test (CCTDI) and the California Critical Thinking Skills Test (CCTST) on both students' disposition toward critical thinking and critical thinking skills. They used a rigorous pretest, posttest and post-posttest control group design. When the Posttest was compared to the post-posttest for the two tools, however, there was a statistically significant difference between the pretest-to-posttest results from CCTDI and CCTST (p= 0.001 for all) (Miri, et al., 2007).

Teaching for CT is important, as students must be able to explore new ways of doing things in order to help them adapt to their everyday living environments (Bransford, et al., 1999, Nemanich, Banks, & Vera, 2009). Hence, the assumption for this study is that when students' thinking capacity is activated, it is only then that they can transfer knowledge. The purpose of this study is to promote higher order thinking skills among the science university students and assess the tools for promoting knowledge transfer. The following assumptions were made:

a) Students' critical thinking can be developed if educators ask higher level questions, use active teaching strategies, and demonstrate good facilitation skills

b) Critical thinking can promote deeper learning and students' knowledge transfer.

Therefore, if educators want to prepare students for a higher level of critical thinking at university level, they must use higher order thinking tools in their teaching approaches, and technologies can help them overcome this challenge.

Methodology

Research design

To measure the effects of the crossed method (Flipped Classroom-Scaffolding Model), a quasi-experimental design within the classrooms was used in a mixed method study (Lodico, Spaulding. & Voegtle, 2006). Quantitative data were collected from post-study tests. The tests comprised of questions based on the higher order thinking level of the Bloom's Taxonomy of objectives, while qualitative data, on the other hand, were collected from the classroom field notes (Sanjek, 1990).

Participants and Sampling

A purposive sampling method was used in this study. Purposive sampling is the sampling method where participants are selected according to certain criteria relevant to particular research question. For example, taking into account the sample size and time frame for the research (Sale, Lohfeld & Brazil, 2002). The class that participated in the study was chosen because of the size n=76, since this a quantitative study. However, even though the class sample size was reduced in the process as some students did not attend the classes, which effectively reduced the sample size to n= 36.

The study was conducted at the University of Namibia Main campus in the Department of Chemistry and Biochemistry. Thirty-six (n=36) third year science students aged 15 to 18 years from three classes, and majoring in Chemistry, Biology and Biochemistry, participated. The students were divided into 2 groups. The groups covered the same general topic: electron transport chain and phosphorylation under glucose metabolism. The flipped classroom approach was applied to all three classes throughout the study. Only the way they were approached, differed from class to class. The researcher headed all the three classes at the same venue at various times over the duration of a week and used a flipped classroom teaching approach, with different scaffolding tools attached. Within the design, most of the variables were kept as constant as possible, and only a few were changed (the tool used) in order to ensure the validity of the method.

Data Collection, Analysis and Instruments

The class materials were posted on the class portfolio (class e-mail) three days before the class. Outside the classroom, students accessed the provided videos via the Google drive; these videos were accompanied by some motivational questions based on the concepts in the two videos. Students were expected to ask questions and comment on the lecture videos. In the classroom, the researcher addressed all the questions and comments posed by the students before giving them some scaffolding tools for the three experimental groups. The data was analysed, using one way ANOVA at 95% level of confidence, and compared to each other to test for variation of the means.

Class setting

The first group was provided with a higher order thinking tool by means of a question card or prompt, composed of questions based on the topic. The tool was given to engage students into thinking of higher order and to enhance their understanding in order to enable them to transfer what they learned from the lesson to other similar problems. The second group was a control group, hence no tool was given.

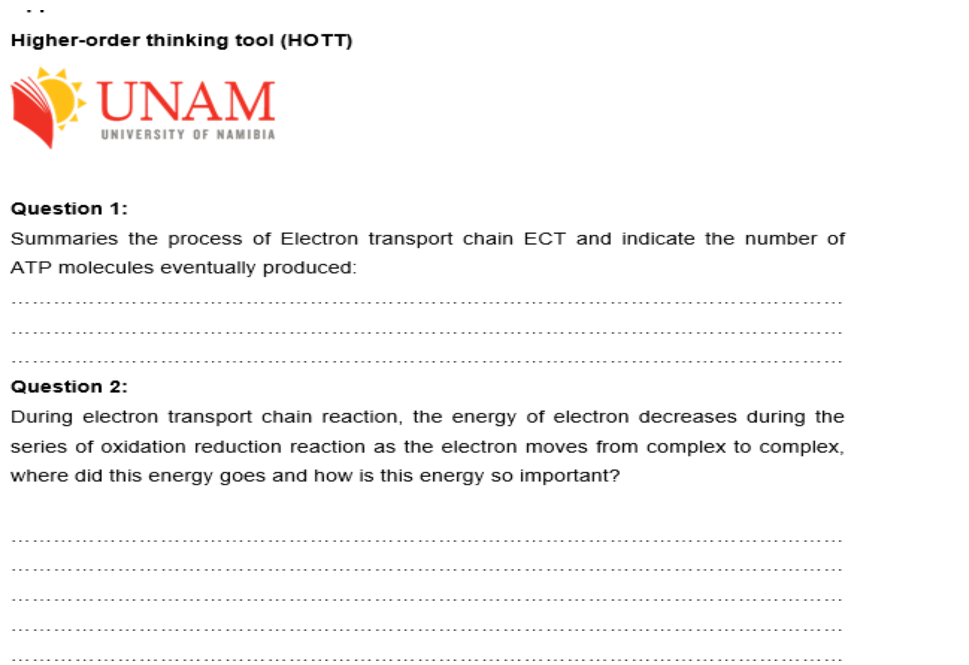
All the lessons were given in the same venue, but on different dates, following the weekly time table for the module under study. Each group was then allocated a 55 minutes session. Before they commenced with the lesson, the researcher ensured that instructions were made clear to students. The experimental class received support throughout the study to help students to remain focused and get the expected solutions to the problems.

During the class session for Higher Order Thinking Tools (HOTT), questions were explained to the whole group first before extra support was given to them in their respective groups. All students were told that they were free to ask and discuss the concept with their peers and the facilitator. They all worked in groups to foster student-student collaboration, and also to make the session more interactive. The researchers monitored students' progress during the session to avoid misconceptions, motivate them, and to engage them into meaningful dialogues on the subject with their peers.

The idea is to engage students into more active learning and pave away from the passive lecturer centered learning strategy to a more active student-centered learning approach via integration of technology into the teaching and learning system.

Higher Order Thinking Tools

Based on the Bloom's Taxonomy of learning, Bloom categorised thinking into two groups: one comprising of the three levels, Knowledge (remember), Comprehension (understand) and Application (apply), categorised as Lower Order Thinking Skills (LOTS), the other comprising Analysis, Synthesis (create) and Evaluation, called Higher Order Thinking Skills (HOTS) (Narayanan & Adithan, 2015). Hence, the tool was created based on the Higher Order Thinking Skills in order to enable students to create and evaluate their own understanding. A Higher Order Thinking Tool was used in the Bioenergetics and Metabolisms class to enhance students' ability to transfer knowledge. An example of HOTT is depicted in Figure 2 below (see Annex 3 for complete tool).



Higher-order thinking tool (HOTT)

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Question 1:
Summaries the process of Electron transport chain ECT and indicate the number of ATP molecules eventually produced:

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Question 2:
During electron transport chain reaction, the energy of electron decreases during the series of oxidation reduction reaction as the electron moves from complex to complex, where did this energy goes and how is this energy so important?

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Figure 2: Example of HOTT

Transfer test

In order to evaluate the effectiveness of the higher order thinking scaffolding tool, students were given a transfer test. The transfer test was given to the whole class on the day that the class attendance was expected to be high. Questions were at higher thinking level to ensure the validity of the tool. Because of time limits, the researcher had to share the class time (55 minutes) with the lecturer and the time frame allocated for the study. The researcher gave only five (5) multiple choice questions of 2 points each. The test composed of questions that required Critical Thinking (CT), and most of these questions were adopted from:

http://www.namrata.co/category/metabolism-carbohydrates/multiple-choice-questions-metabolism-carbohdrates/. The HOTT group n=18 performed better than the group that used both tools and the control group that used none of the two tools.

Results

The data were analysed using analysis of variance (ANOVA), a parametric test. The decision was made based on the normality test that was run on all four means at α>0.05 level of significance, using a Shapiro-Wilk's test p>0.05, hence positive. According to Shapiro and Wilk (1965), and the visual inspection of the histogram, normal Q-Q plots, and a box plots showed that the scores from the two different treatments were fairly normally distributed (Mendes & Pala, 2003). The scores for posttest, p= 0.079, transfer, p= 0.001, and retention with p= 0.047, are as shown in Table 1.

Table 1: The Shapiro-Wilk test for normality results

Shapiro-Wilk test	Df	Sig.(p value)
Test score for posttest	65	0.079
Test score for transfer test	65	0.001

Posttest

The overall performance from the posttest in the four groups was found to have no significant difference. When a One Way ANOVA was run at 95% level of confidence, the p-value was found to be greater than 0.05 (p> 0.05), showing no significant difference in the posttest mean among the four treatments, with f=1.307, and p=0.28. The summary of the results is displayed in Table 2.

Table 2: Analysis for post test scores for the two groups

Treatments	N	Mean	SD	P value
HOTT posttest	20	7.25	1.41	0.28
Control group posttest	20	6.13	2.42	0.28

Test score for transfer test

Students' overall performance was good in the transfer test. One Way ANOVA was run to find the means and, most importantly, to establish whether there is a significant difference between the means. The descriptive statistics at df=3 and F= 1.11 gave a value of p=0.35, which means there is no significant difference between the means for the transfer test among the two treatments. Table 3 shows more details about the mean, sample size, and standard deviation for transfer tests:

Table 3: Transfer test analysis

	N	Mean	Standard Deviation
HOTT transfer test	18	4.89	2.32
Control group transfer	15	4.27	3.10

Discussion

Effectiveness of Higher Order Thinking Scaffolding Tool as an Instrument that Promotes Knowledge Transfer

The goal of this study was to test the effectiveness of Higher Order Thinking Tools as instruments that promote students' knowledge transfer in a science class at the University of Namibia. This was done by using the Higher Thinking Order Scaffolding Tool (the question card) in a flipped classroom.

In general, students performed well in the transfer test. The results showed no statistically significant difference between the means control M=4.27, and Higher Order Thinking Tools M=4.89, respectively. The current study suggests that HOTT Tool Scaffolding has no significant effect on students' ability to transfer knowledge, even in a flipped classroom environment.

When analysing the test scores for the transfer test from the groups, the group that was using Higher Order Thinking Tools (38%) students scored in the range 60%-100% with 100% being the highest and the control group (47% of students) scored on average 50%. Though there was no statistically significant difference found, students from the HOTT group scored slightly better (M= 4.89) than the control group (M=4.27). This design faced several challenges that may result in a low efficiency of the tools, such as the time frame allocated for the study, which was too short: two days only. The study findings support the results of the Stephenson and Sadler-McKnight (2016) findings on the use of the Science Writing Heuristics SWH Method in a Chemistry laboratory to develop higher order thinking among chemistry students over a period of 24 weeks. Stephenson and Sadler-McKnight found that there was a significant difference between the two posttest means. Additionally, our findings are consistent with Miri and others (2007), who assessed the effect of purposive teaching method (case study) using two Critical Thinking CT tests, the California Critical Thinking Disposition Inventory Test (CCTDI) and the California Critical Thinking Skills Test (CCTST) on both students' disposition toward Critical thinking and critical thinking skills over a period of three academic years. A paired comparison test t test was run on test scores from both tools (CCTDI and CCTST). Findings indicated that there was no significant difference when the Posttest was compared to the post-posttest for the two tools. However, there was a statistically significant difference between the pre-test-to-posttest comparison from both CCTDI and CCTST (p= 0.001 for all) (Miri et al., 2007). If we compare the current study to the literature, there is a significant difference in the time allocated for the two studies. The current study was conducted over the course of a week, whilst the other studies were conducted over a lengthy period (one full semester and 3 academic years, respectively). The researchers confidently made an assumption that it requires a long period of time for critical thinking abilities to develop (Miri et al., 2007). Therefore, due to the nature and the design of the current study, HOT Tools could not execute faultless results.

Posttest

Students wrote the posttest to provide the research with data that can help in making conclusions on knowledge transfer. As mentioned earlier in this paper, for students to be able to transfer knowledge effectively, they must first learn and understand. The posttest was given as a measure learning threshold. The mean for the HOTT group (M=7.25) was slightly higher than that of the other three groups: Analogy M= 6.84, Analogy HOTT combination M= 6.12, and the control group M= 6.13 were greater than that for the analogical HOTT combination. Researchers assumed that the Flipping classroom model also contributed to the learning. This was assumed because the control group performance was close to the score of the group that used scaffold tool. Ng (2014) emphasised that, "during inverted classroom model, students would focus on and engage in activities that foster deeper understanding and higher order thinking through discussions, practical work and problem solving tasks that they do individually or collaboratively in small groups" (p. 18).

Conclusion

The use of the scaffolding tool in education is one of the most common studies found in current literature, although most of the studies focused on primary and high school learners. This study focused on the use of scaffolding tools at university level. In addition, the study integrates the scaffolding metaphor into the flipped classroom, something that has not been researched on before.

The study concludes that scaffolding tools were effective in a flipped or inverted class environment. An important conclusion made from this study was on the effects of the HOTT scaffolding tool used in this study in the flipped classroom environment. The HOTT scaffolding tool was compared to the control group for knowledge transfer. The results show that there is no statistically significant difference between the two means p= 0.051, hence the effect of HOTT on knowledge transfer was found to be minimal.

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Annex 1

Posttest

Bioenergetics and metabolisms Post-test; Electron transport chain reaction and phosphorylation

The proper sequence of stages in electron transport chain is
Cytochrome c, cleavage and rearrangement, NADH, ATP generation
Cleavage and rearrangement, glucose priming, ATP generation, oxidation
Glucose priming, Coenzyme Q, Cytochrome c, ATP generation
Complex I, oxidation, glucose priming, cleavage and rearrangement
NADH, Complex I, Coenzyme Q, Complex III, Cytochrome c , Complex IV and O2
Under normal conditions, as electrons flow down the electron transport chain of the mitochondria:
NADH and FADH2 are oxidized.
The pH of the matrix increases.
The electrons lose free energy.
An electrochemical gradient is formed.
All of the above.
Which of the following statements about the electron transport chain is NOT correct?
It is located in the inner mitochondrion membrane
Cytochrome c accepts electrons from complex II
Cytochrome oxidase (complex IV) accepts electrons from Cytochrome c
Complex I is called NADH dehydrogenase
Coenzyme Q accepts electrons from complex I and complex II

Which of the following statements about oxidative phosphorylation is NOT true (Note! The electron transport chain or electron transfer chain is abbreviated etc.)
The movement of electrons down the etc. only happens if protons are pumped out of the mitochondria
If the proton gradient is too high, electrons will not move through the etc.
A proton gradient is formed across the outer mitochondria membrane
The free energy of the proton gradient can be used to create high energy bonds
Protons enter the mitochondria if, and only if, ATP is synthesized
All of the following statements are true EXCEPT
Complex II accepts two electrons from FADH2 of succinate dehydrogenase of the TCA cycle
Complex I donates two electrons to Coenzyme Q
If the ATP/ADP ratio is low enough, the oxidation of succinate will produce about 1.5 ATPs
When succinate is oxidized, protons are pumped at complex I
When succinate is oxidized, protons are pumped at complex IV
The function of an electron in the electron transport chain is
To transfer energy from complex II to complex I
To pump hydrogen ions using complex II
To use its free energy to pump protons against their concentration gradient
To combine with phosphate when ATP is synthesized
To react with ATP synthase
All of the following statements about cytochromes of the electron transport chain are true EXCEPT
They are heme proteins
They serve as electron carriers in oxidation-reduction reactions
They all have the same energy when reduced
When reduced, iron is in the +2 state
When oxidized, iron is in the +3 state

Cytochrome oxidase
Uses H2O as a substrate
Produces HOOH as a product
Cannot function if oxygen is absent
Accepts electrons from hydrogen ions
Uses ADP and Pi as substrates
What four items go into the electron transport chain and what four items come out?

A.O2, NADH, FADH2 and ADP go in to produce H2O, NAD, FAD and ATP

B.Pyruvate, ADP, NAD and FAD go in to produce CO2, NADH, FADH2 and ATP.

C.ATP, Pyruvate, FADH2 and NADH go in to produce ADP, H2O, NADH and FADH2

D.H2O, Pyruvate, ADP and FADH go in to produce O2, FADH2, ATP and NAD

E.NADH, ADP, FADH2 and CO2 go in to produce Pyruvate, ATP, NAD and FAD

Fill in the missing words:
In the mitochondrial electron transport chain electrons move from an A……………….. donor (such as NADH) to a terminal B……………. (O2) via a series of redox reactions. These reactions are coupled

to the creation of a proton gradient across the C ……………………………. membrane. The resulting trans-membrane proton gradient is used to make D………………………. via ATP synthase.

Annex 2

Transfer Test
Group Name………………………………… Date……………………….
Electron Transport Chain ECT and Oxidative Phosphorylation
Instructions:
Circle the correct answer

Question 1:
An 18 years old cricket player sustains a compound fracture on the field. He is taken for surgery, during which anesthesiologist notes a significant increase body temperature (104F). There is a suspicion of malignant hyperthermia. Which of the following component of ECT is likely to be responsible for this phenomenon?
Complex I
Complex II
Complex III
Complex IV
ATP synthesis complex

Question 2:
MELAS is a mitochondrial disorder characterized by mitochondrial encephalopathy, lactic acidosis and stroke like episode. It is an inherited condition due to NADH: Q oxidoreductase (complex I) or cytochrome oxidase (complex IV) deficiency caused by a mutation I mitochondria DNA and may be involved in Alzheimer's disease and diabetes mellitus. Due to lack of functional mitochondria, what would be the net ATP that would be produced from one molecule of Glucose?
1
2
4
0
8

Question 3:
A 63 years old man with a strong family history of Parkinson disease begins to show some signs of this disease "pin rolling tremors". He visited his neurologist, who guides him about the recent research about coenzyme Q that may stall the development of the disease. This component of ECT normally………
Receives electrons directly from NADH
Receives electrons directly from complex IV
Receives electrons directly from Complex I (FMN)
Transports ATP to the cytoplasm
Contains Heme

Question 4:
A 32n years old women working in a laboratory consume cyanide and was rushed to hospital. She was declared dead upon reaching the hospital. Cyanides know inhibitor of Electron Transport

Chain 9ETC). Cyanide mostly binds cytochrome oxidase so as to prevent the binding of Oxygen. Which complex of ECT have been Inhibited?
Complex I
Complex II
Complex III
Complex IV
All of the above

Question 5:
The cytochromes are iron-containing hemoprotein in which the iron atom oscillates between Fe^{3+} and Fe^{2+} during oxidation and reduction. Most of the cytochromes of the electron transport chain are classified as dehydrogenases. Which out of the following cytochrome is not a dehydrogenase?
NADH-Q oxoreductase (complex I)
Q-cytochrome c oxidoreductase (complex III)
Cytochrome c oxidase (complex IV)
Succinate Q reductase (complex II)
Cytochrome c
THANK YOU!!!!

Annex 3

Higher-order thinking tool (HOTT)

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Question 1:
Summaries the process of Electron transport chain ECT and indicate the number of ATP molecules eventually produced:
……
……

Question 2:
During electron transport chain reaction, the energy of electron decreases during the series of oxidation reduction reaction as the electron moves from complex to complex, where did this energy goes and how is this energy so important?
……
……
……