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The Moderating Effect of Prior Knowledge on Higher Order Thinking Skills in the Interactive Multimedia Learning Environment

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Abstract
This study aims to identify the moderating effect of prior knowledge on the achievement of form four Biology students (aged 16 years) in Malaysia in higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills. To this end, a quasi-experimental design was used. The sample consists of 181 respondents where 90 respondents were assigned to the experimental group and 91 respondents comprised the control group. The respondents were selected by a four-stage cluster sampling. The experimental group was subjected to learn Nutrition through an interactive multimedia courseware named Nutri-Score, whereas the control group learnt the topic traditionally. Pre-test and post-test consisting of one short item question and three essay questions based on Rubrics for Specific Tasks or Situations from Marzano Model were designed to measure the respondents' achievement. Findings revealed a positive effect on the experimental group's achievement in higher order thinking skills, classifying skills, comparing and contrasting skills but not in problem solving skills. Moreover, learners with high and average prior knowledge showed a higher improvement in academic achievements compared to those with low prior knowledge. This result contradicts to the assumption of the cognitive theory of multimedia learning that learners with low prior knowledge would benefit from its principles more than learners with high prior knowledge.
Keywords: Prior Knowledge, Moderator Variable, Higher Order Thinking Skills, Interactive Multimedia, Biology, Nutrition

Introduction

Curriculum strengthening is one of the key changes made by the Ministry of Education Malaysia to prepare students for the challenges of the Industrial Revolution 4.0. Apart from the curriculum, teachers' teaching approaches also need to be adapted to address the challenges of this revolution. The important skills that students need to master in the 21st century can be used as a benchmark in selecting the teaching methods. The important skills are information and communication skills, thinking and problem solving skills as well as interpersonal and self-directed skills. Information and

communication skills can be achieved through the use of information and communication technology. Teachers' guidance is needed so that students can master the use of gadgets to find information, not just for entertainment. Higher order thinking skills must be acquired by students to enable them to create innovative products, solve complex life problems and compete internationally. Interpersonal and self-directed skills also cannot be ignored because human values cannot be applied to the robots created.

Biology is a broad branch of science and contains lots of abstract and microscopic concepts and science processes (Campbell et al., 2018). Example is Nutrition topic from the Form Four Biology curriculum which contains physiological processes such as osmosis, digestion, absorption and assimilation. The problem is that students are difficult to visualize and think at the molecular level (Mnguni, 2014). Hence, teaching and learning through listening to lectures while copying notes from the white boards or Powerpoint slides are no longer relevant. Rigid images to illustrate the physiological processes which printed in the Biology textbooks and reference books then widely distributed can lead to misconceptions among students (Rian, Radjawaly & Stories, 2016; Swain, 2012). It is time for every teaching aid used not only to assist in teaching and learning Biology but also to enhance the skills that are so important in the 21st century such as higher order thinking skills.

Background of Study

There are many multimedia learning environments for Science and Mathematics. They often combine the description of a complex system or procedure in written or oral form with animated presentation (Moreno, 2005). Multimedia learning which properly designed, has been shown to enhance student's understanding as demonstrated in problem solving activities (Mayer & Moreno, 2003). Nonetheless, research by research has shown that effective multimedia programs involve pedagogical agents (Lee, 2013; Moreno, 2005). So in this study, we developed an interactive multimedia courseware with a pedagogical agent named Nutri-Score for teaching and learning the topic of Nutrition. Respondents in the treatment group will study Nutrition using the Nutri-Score while respondents in the control group study Nutrition traditionally.

Nutri-Score is loaded with seven animations to illustrate the process of peristalsis, digestion, assimilation and defecation. The food digestion processes illustrated are which in human, ruminant which is cow and rodent which is rabbit. Nutri-Score adheres to the Malaysian curriculum specification, stand-alone where students can learn at their own pace without teachers and it is interactive. The principles embodied in multimedia theories, learning theories and contextual learning strategies are applied in its design and development. Findings of the literature review indicate that less attention is given to how learning in the interactive multimedia environment is influenced by individual differences factors such as spatial ability, skills, prior knowledge and misconceptions. Therefore, this study will focus on the effect of respondents' prior knowledge on multimedia-based learning. Prior knowledge is used as a moderator variable (Johnson, Osogul & Reisslein, 2014).

Malaysian students are found to be weak in the items of comparing and contrasting skills (Malaysian Examinations Syndicate, 2014 & 2013). They are also weak in TIMSS and PISA on items that test problem-solving skills (Dossey, O'Sullivan & Gonzales, 2006). However, studies on these skills are still lacking. Thus, we chose the comparing and contrasting skills, problem solving skills and another skill which is the classifying skills as the dependent variables. The combination of these three

skills produces higher order thinking skills according to Marzano's New Taxonomy and they are reflected in the learning outcomes of Nutrition topic. We chose Marzano's New Taxonomy because it offers teachers a more practical way to distinguish low and high order thinking skills compared to Bloom's Taxonomy (Marzano & Kendall, 2007).

Objective

The objective of this study is to compare the difference in achievement of higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills among students with different levels of prior knowledge from the treatment and control groups.

Research Questions

There are four research questions in this study:

(i) Is there a significant difference in achievement of higher order thinking skills among the high performance, average performance and low performance students from the treatment and control groups?

(ii) Is there a significant difference in achievement of classifying skills among the high performance, average performance and low performance students from the treatment and control groups?

(iii) Is there a significant difference in achievement of comparing and contrasting skills among the high performance, average performance and low performance students from the treatment and control groups?

(iv) Is there a significant difference in achievement of problem solving skills among the highperformance, average performance and low performance students from the treatment and control groups?

Methodology

This study involved quasi-experimental design of pre-post test of unbalanced groups (Table 1). The quasi-experimental design was used in this study because random distribution was not possible in the selection process of respondents to create balanced groups of all aspects (Othman, 2013). Respondents in the control group studied Nutrition traditionally while the treatment group used Nutri-Score. The cooperative learning method which proposed by King, Goodson and Spiritual (1997) to teach higher order thinking skills was applied to both groups. We set out three options for cooperative learning methods for the teachers to implement to the control groups which are jigsaw, small-group teaching and group investigation. For the respondents in the treatment group, we chose the think-pair share method which work in pairs.

The Entry Test was administered in conjunction with the pre-test to check the homogeneity between the respondents in the treatment and control groups. The Entry Test contains 30 multiple-choice questions for five topics in Form Four Biology prior the topic of Nutrition. Then, respondents were asked to answer the pre-test which consists of one short answer item question and three essay questions. Short answer item question tests the ability to classify living organisms. An essay question tests the comparing and contrasting skills of the human, rodent and ruminant digestive systems. An essay question tests the problem solving skills of obesity among adolescents. Another essay question tests the problem solving skills of a chronic bile duct patient. After studying Nutrition for four cycles, all respondents answered the post-test which is similar to the pre-test. All question items in the pre-

test and post-test were constructed using Rubrics for Specific Tasks or Situations (Marzano, Pickering, & McTighe, 1993) and aligned with the level of the Malaysian Certificate of Education (SPM) questions.

Table 1. Methodology of quasi-experimental Design

Group	Intervention	Illustration of methodology
Treatment	Nutri-Score	$O_1 \longrightarrow X_1 \longrightarrow O_2$
Control	Traditional	$O_1 \longrightarrow X_2 \longrightarrow O_2$

Guideline :

X_1 = Learning with Nutri-Score
X_2 = Learning traditionally
O_1 = Pre-test and Entry Test
O_2 = Post-test

The cluster sampling method which consists of four simple random selections was implemented until the sample was obtained. The sampling method with four random selections is called four-stage cluster sampling (Creswell, 2008). We have chosen the most manageable areas of the Northern Peninsular Malaysia comprising the states of Perlis, Kedah, Penang and Perak. The first vote was obtained by Kedah and Penang. The second vote draws the districts, the third vote draws the schools and the fourth vote draws the treatment and control group. The distribution of the respondents is shown in Table 2.

Table 2. The Distribution of Respondents based on States, Districts and Schools

State	District	School	Group				Total (No.)	Percentage (%)
			Control		Treatment			
			No.	%	No.	%		
Kedah	P	A	30	32.97	23	25.56	110	60.77
	Q	B	29	31.87	28	31.11		
Penang	R	C	18	19.78	21	23.33	71	39.23
	S	D	14	15.38	18	20.00		
Total			91	100.00	90	100.00	181	100.00

The relationship between the independent variables, the dependent variables and the moderator variable are illustrated in Figure 1. The independent variables are the learning modes which either learning Nutrition traditionally or through Nutri-Score. The dependent variables are higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills. The moderator variable is the students' prior knowledge. Prior knowledge was measured based on the respondents' achievement in the Form Three Assessment. Respondents who obtained A grade in Science are placed in the high performance group. Respondents who obtained B grade in Science

are placed in the average performance group while the C grade are placed in the low performance group. The effect of the independent variables on the dependent variables under the influence of the moderator variable was studied in this study

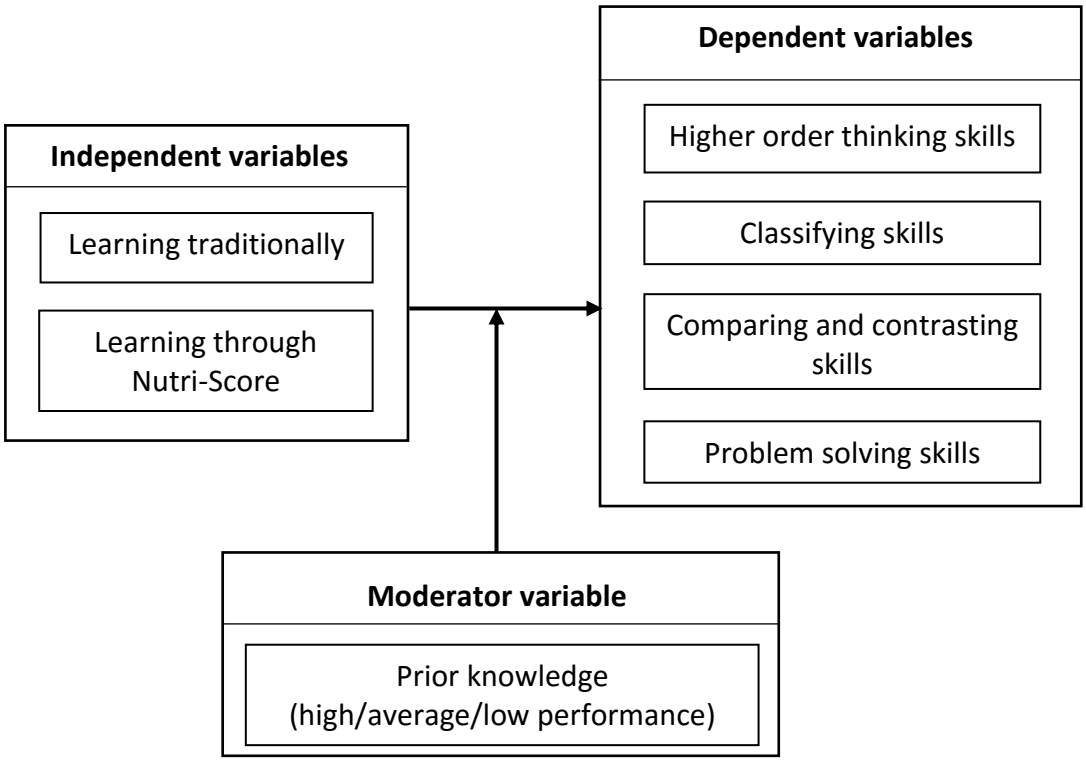

Figure 1. Relationship between the variables of the study

Results

A MANCOVA test was performed simultaneously to all four dependent variables based on performance group to avoid error I.

Homogeneity

The Levene test of the one-way ANOVA was conducted on the Entry Test scores to test whether the respondents from the treatment and the control group were equivalent in terms of their prior knowledge for the five topics before Nutrition. The result in the Table 2 shows that the significance level of the Levene test exceeds .05. Therefore there is no significant difference for the influence of students' prior knowledge from both the treatment and the control groups ($F(1,179) = 0.107$, $p = .744$). This confirms that students in both the treatment and the control groups are homogenous in terms of their prior knowledge.

Table 2. Analysis of the Levene test in one-way ANOVA for the Entry Test score across groups

Dependent variable	Levene test, *F*	*df*1	*df*2	*p*
Entry test	0.107	1	179	.744

High Performance Group

The result of the Pillai's Trace Multivariate analysis in Table 3 shows that generally there is a significant effect by the high performance group [$F(4,42) = 9.893$, $p < .05$] on the higher order thinking skills, classifying skills, comparing and contrasting skills and problem-solving skills.

Table 3. Analysis of Multivariate Pillai's Trace according to learning modes towards dependent variables

Independent variables	Value	*F*	Hypothesis *df*	Error *df*	*p*
Groups	.485	9.893	4.000	42.000	.000

Analysis of the Univariate Tests of Between-Subjects Effects or ANCOVA on each of the dependent variable (Table 4) reveals a significant effect by the high performance group on higher order thinking skills [$F(1,45) = 11.209$, $p < .05$], classifying skills [$F(1,45) = 8.483$, $p < .05$], comparing and contrasting skills [$F(1,45) = 31.371$, $p < .05$] and problem solving skills [$F(1,45) = 2.495$, $p > .05$]. R^2 values show that the high performance group contributed 55.0% change to the higher order thinking skills, 20.6% change to the classifying skills, 67.2% change to the comparing and contrasting skills and 20.9% change to the problem solving skills.

Table 4. Analysis of ANCOVA for each of the dependent variable

Source	Dependent variables	Total square type III	*df*	Square root mean	*F*	*p*	R^2
High performance group	Higher order thinking skills	978.271	1	978.271	11.209	.002	.550
	Classifying skills	2861.275	1	2861.275	8.483	.006	.206
	Comparing and contrasting skills	3904.032	1	3904.032	31.371	.000	.672
	Problem solving skills	853.576	1	853.576	2.495	.121	.209

The result of the Estimated Marginal Means analysis (Table 5) shows that for each of the dependent variable, the adjusted mean of the treatment group exceeds the adjusted mean of the control group except for the problem solving skills. For the higher order thinking skills, the mean of the treatment group which is 41.543 exceeds the adjusted mean of the control group which is 31.697 by 9.846. For the classifying skills, the mean of the treatment group which is 57.915 exceeds the mean of the control group which is 41.077 by 16.838. For the comparing and contrasting skills, the mean of the treatment group which is 32.056 exceeds the mean of the control group which is 12.388 by

19.668. For the problem solving skills, the mean of the control group which is 41.286 exceeds the mean of treatment group which is 32.089 by 9.197.

The Post Hoc Bonferroni Adjusted Pairwise Comparison test (Table 5) confirmed that for higher order thinking skills, the adjusted mean of the treatment group which exceeds the control group by 9.846 is significant ($p < 0$). For the classifying skills, the mean of the treatment group which exceeds the control group by 16.838 is also significant ($p < 0$). For the comparing and contrasting skills, the mean of the treatment group which exceeds the control group by 19.668 is also significant ($p < 0$). On the other hand for the problem solving skills, the mean of the control group exceeds the mean of the treatment group by 9.197 and the difference is not significant ($p > 0$).

Table 5. Analysis of Estimated Marginal Means Test and Post Hoc Bonferroni Adjusted Pairwise Comparison for each dependent variable of high performance students across groups

Estimated Marginal Means				Post Hoc Bonferroni Adjusted Pairwise Comparison	
Dependent Variables	Group	Adjusted mean	Standard error	Mean difference	*p*
Higher order thinking skills	Treatment	41.543	1.781	9.846	.002
	Control	31.697	2.230		
Classifying skills	Treatment	57.915	3.502	16.838	.006
	Control	41.077	4.385		
Comparing and contrasting skills	Treatment	32.056	2.127	19.668	.000
	Control	12.388	2.663		
Problem solving skills	Treatment	32.089	3.527	-9.197	.121
	Control	41.286	4.416		

In conclusion, learning mode through Nutri-Score by the high performance treatment group produce better higher order thinking skills compared to the traditional learning mode. In particular, learning mode through Nutri-Score produces better achievement in classifying skills as well as in comparing and contrasting skills for the high- performance students. However for problem solving skills, the traditional learning mode by the high performance students results in better achievement although it is not significant.

Average Performance Group

The result of the Pillai's Trace Multivariate analysis in Table 6 shows overall a significant effect by the average performance group [$F(4,74) = 8.676$, $p < .05$] on higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills. In conclusion, average performance from either the treatment group or the control group is a factor contributing to the achievement in higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills of the respondents.

Table 6. Analysis of Multivariate Pillai's Trace for the effect of learning mode towards dependent variables

Independent variable	Value	*F*	Hypothesis *df*	Error *df*	*p*
Group	.319	8.676	4.000	74.000	.000

The data was further analyzed using the Tests of Between-Subjects Effects or ANCOVA test for each dependent variable (Table 7). It shows that there is a significant effect of the average performance on higher order thinking skills [$F(1,45) = 18.315$, $p < .05$], classifying skills [$F(1,45) = 17.493$, $p < .05$], comparing and contrasting skills [$F(1,45) = 21.354$, $p < .05$] and problem solving skills [$F(1,45) = 4.069$, $p < .05$]. R^2 values show that the average performance group accounted for 34.8% change in higher order thinking skills, 18.9% change in classifying skills, 33.7% change in comparing and contrasting skills and 13.9% change in problem solving skills.

Table 7. ANCOVA analysis for each dependent variable of the average performance students from each group

Source	Dependent variables	Total square type III	*df*	Mean square	*F*	*p*	R^2
Average performance group	Higher order thinking skills	1595.380	1	1595.380	18.315	.000	.348
	Classifying skills	6014.332	1	6014.332	17.493	.000	.189
	Comparing and contrasting skills	2966.495	1	2966.495	21.354	.000	.337
	Problem solving skills	956.730	1	956.730	4.069	.047	.139

The result of the ANCOVA test was further explained by the Estimated Marginal Means analysis as shown in Table 8. It shows that for each dependent variable, the mean of the treatment group always exceed the mean of the control group except for the problem solving skills. For higher order thinking skills, the mean of the treatment group score which is 35.315 exceeds the control group mean score which is 26.129. For classifying skills, the treatment group adjusted mean which is 60.310 exceeds the control group adjusted mean which is 42.474. For the comparing and contrasting skills, the mean of the treatment group which is 20.702 exceeds the mean of the control group which is 8.776. For problem solving skills, the mean of the control group which is 23.087 exceeds the mean of the treatment group which is 30.201.

Subsequently, the Post Hoc Bonferroni Adjusted Pairwise Comparison (Table 8) test was performed to determine whether the adjusted mean difference for the treatment group and control group is significant or not. The result confirms that for higher order thinking skills, the mean of the treatment group which exceeds the control group by 9.186 is significant ($p < 0$). For the classifying skills, the mean of the treatment group which exceeds the control group by 17.836 is also significant ($p < 0$). For the comparing and contrasting skills, the mean of the treatment group exceeds the control group by 12.527 is also significant ($p < 0$). However for the problem solving skills, the mean of the

control group exceeds the mean of the treatment group by 7.114 and the difference is significant ($p < 0$).

Table 8. Analysis of Estimated Marginal Means and Post Hoc Bonferroni Adjusted Pairwise Comparison for each dependent variable of average performance students across groups

Estimated Marginal Means				Post Hoc Bonferroni Adjusted Pairwise Comparison	
Dependent variables	Group	Adjusted mean	Standard error	Mean difference	*p*
Higher order thinking skills	Treatment	35.315	1.576	9.186	.000
	Control	26.129	1.422		
Classifying skills	Treatment	60.310	3.130	17.836	.000
	Control	42.474	2.825		
Comparing and contrasting skills	Treatment	20.702	1.990	12.527	.000
	Control	8.176	1.796		
Problem solving skills	Treatment	23.087	2.589	-7.114	.047
	Control	30.201	2.336		

In conclusion, learning mode through Nutri-Score by the average performance treatment group produces better overall higher order thinking skills compared to the traditional learning mode by the average performance control group. In particular, the learning mode using Nutri-Score produces better achievement in classifying skills as well as in comparing and contrasting skills for the students of average achievement. However for the problem solving skills, a traditional learning mode by the average performance students results in better performance.

(iv) Low performance group

The result of Pillai's Trace Multivariate analysis in Table 9 shows overall a significant effect by the low performance group [$F(4,47) = 13.371$, $p < .05$] on higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills. In conclusion, the low performance of either the treatment group or the control group is a factor contributing to the achievement in higher order thinking skills, classifying skills, comparing and contrasting skills and problem solving skills of the respondents.

Table 9. Analysis of Multivariate Pillai's Trace for the effect of learning mode towards dependent variables

Independent variable	Value	*F*	Hypothesis *df*	Error *df*	*p*
Group	.532	13.371	4.000	47.000	.000

Univariate Test of Between-Subjects Effects or ANCOVA test on each dependent variable (Table 10) shows a non-significant effect of low performance on higher order thinking skills [$F(1,50) = 0.747$, $p > .05$] and classifying skills [$F(1,50) = 0.007$, $p > .05$]. R^2 values indicate that the low

performance group contributes 9.4% change to higher order thinking skills and 0% change to classifying skills. However, there is a significant effect of low performance group on comparing and contrasting skills [$F(1,50) = 7.535$, $p < .05$] and problem solving skills [$F(1,50) = 26.977$, $p < .05$]. R^2 values indicate that the low performance group contributes 17.6% change in comparing and contrasting skills and 43.1% change in problem solving skills.

Table 10. ANCOVA Analysis for Each Dependent Variable

Source	Dependent variables	Total square type III	*df*	Mean square	*F*	*p*	R^2
Low performance group	Higher order thinking skills	93.354	1	93.354	.747	.392	.094
	Classifying skills	5.094	1	5.094	.007	.932	.000
	Comparing and contrasting skills	1404.893	1	1404.893	7.535	.008	.176
	Problem solving skills	4412.967	1	4412.967	26.977	.000	.431

The result of the Estimated Marginal Means analysis (Table 11) shows that for each dependent variable, the adjusted mean of the treatment group always exceed the adjusted mean of the control group except for classifying skills and problem solving skills. For higher order thinking skills, the mean of the treatment group is 28.706 which exceeds the control group mean which is 26.048 by 2.659. For classifying skills, the mean of the control group which is 45.180 exceeds the treatment group mean which is 44.559 by 0.621. For comparing and contrasting skills, the mean of the treatment group which is 17.826 exceeds the mean of the control group of 7.512 by 10.314. For problem solving skills, the mean control group which is 28.415 exceeds the mean of the treatment group which is 10.136 by 18.279.

Subsequently, the Post Hoc Bonferroni Adjusted Pairwise Comparison (Table 11) test was performed to determine whether the adjusted mean difference for each treatment group and control group is significant or not. The result of this test confirms that for higher order thinking skills, the mean of the treatment group exceeds the mean of the control group by 2.659 is not significant ($p > 0$). For classifying skills, the mean of the control group which exceeds the mean of the treatment group by 0.621 is also not significant ($p > 0$). For the comparing and contrasting skills, the mean of the treatment group which exceeds the mean of the control group by 10.314 is significant ($p < 0$). On the other hand for problem solving skills, the mean of the control group exceeds the mean of the treatment group by 18.279 and the difference is significant ($p < 0$).

Table 11. Analysis of Estimated Marginal Means test and Post Hoc Bonferroni Adjusted Pairwise Comparison for each dependent variable of low performance students across groups

Estimated Marginal Means				*Post Hoc Bonferroni Adjusted Pairwise Comparison*	
Dependent variables	Group	Adjusted mean	Standard error	Mean difference	*p*
Higher order thinking skills	Treatment	28.706	2.236	2.659	.392
	Control	26.048	2.113		
Classifying skills	Treatment	44.559	5.253	-.621	.932
	Control	45.180	4.963		
Comparing and contrasting skills	Treatment	17.826	2.731	10.314	.008
	Control	7.512	2.581		
Problem solving skills	Treatment	10.136	2.558	-18.279	.000
	Control	28.415	2.417		

In conclusion, learning mode using Nutri-Score by the low performance treatment group produces better overall higher order thinking skills compared to the traditional learning mode by the low performance control group. In particular, the learning mode using Nutri-Score results in better achievement in comparing and contrasting skills for low performance students. However for classifying skills and problem solving skills, a traditional mode of learning by low performance students results in better performance.

Discussion

Students have their own existing knowledge gained from their own life experience. How much the prior knowledge in their mental models brought into the classroom, influences their success in learning. The respondents of this study should have basic knowledge of food classes, balanced diet, food tests and food digestion from Science Form Two which was learnt in aged 14. In addition, the prior knowledge of the topic of Nutrition for the respondents in the treatment group can be developed through repeated learning of screen by screen in the Nutri-Score. The prior knowledge of the respondents in the control group for the topic of Nutrition can also be enhanced if the respondents read page by page of the textbook of the Nutrition. Developing an understanding of the concepts before the topic of Nutrition will assist the respondents to understand more complex concepts located at the end of this topic.

The negative achievement of higher order thinking skills by low performance students who learn through Nutri-Score is in line with Huk, Steinke and Floto (2003) and Lowe (2003) who reported that students who do not have proper knowledge will benefit less from animation. Yet this result contradicts to the assumption of the cognitive theory of multimedia learning that learners with low prior knowledge would benefit from its principles more than learners with high prior knowledge. There was no active cognitive process for students in this group learning through Nutri-Score to integrate verbal and pictorial presentations with each other and with their prior knowledge. New information gained by low performance students while learning Nutrition through Nutri-Score cannot

be integrated with their existing scheme which makes it difficult for them to understand new content (Mayer, 2005). The findings of this study also contradict the principle of individual differences in Cognitive Learning Theory of Multimedia Learning (CTML) by Mayer (2001) which argues that the impact of multimedia design has a stronger effect on students with low level of prior knowledge than those with higher level of prior knowledge.

However for problem solving skills, the achievement of students learning through Nutri-Score regardless of high, average or low performance groups is relatively weak. It is possible that the method of using the courseware should be improved. Among them is the implementation of the flipped classroom. To run the flipped classroom, Nutri-Score can be given in advance to all students in the treatment group as Biology textbooks are also given at the beginning of the year to all students. Giving Nutri-Score earlier before studying the Nutrition does not affect the findings of the study because it is up to the students whether they want to learn the whole or part of the content or not directly study the content as well as the students' attitude towards the textbook. This method was supported by Sezer (2017) who demonstrated that students' achievement in technology-based Science learning materials was increased three days before the face-to-face classroom implementation.

Conclusion

The use of multimedia-based teaching aids such as learning tools can help improve students' higher order thinking skills but requires a lot of customization. The implementation of the flipped classroom is one of the suggestions for addressing the identified weaknesses. 21st century educators who are passionate about using multimedia-based teaching aids should be aware of this. They should not hide multimedia-based teaching aids until the classroom.

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