The Effect of Teacher Generated Concept Maps on the Learning of Linear Motion Concepts in Elementary Physics

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ABSTRACT

The aim of this study was to investigate the effect of using teacher generated concept maps on the learning of linear motion concepts in physics. The study used a pre and post-test quasi-experimental design method with a control group. The experimental group ($n= 28$) was taught physics with the aids of concept maps that were generated by the teacher while the control group ($n= 29$) was taught using the conventional method without concept maps. The results show that students using concept maps are more active in class and obtain a statistically significantly higher gain scores on the physics test ($\bar{x} =17.3$) compared to the non-concept mapping group ($\bar{x} =12.9$) with $p < 0.05$. It is concluded that teacher generated concept maps is an effective teaching and learning tool for promoting concept learning of linear motion in physics.

Key Words: Concept Maps; Physics Concepts; Secondary Education.

INTRODUCTION

Deep understanding of physics concepts at the secondary school level (or pre-college level) is important especially for those who intend to pursue a career in the technical disciplines. However, misconceptions in physic at this level are quite common among students (Palmer, 1998). These misconceptions usually persist to interfere with students' ability to master subsequent concepts that are needed for learning at higher levels (Halloun & Hestenes, 1985). Undertaking remediation when the students would be a waste of resources and remediation could be avoided if greater efforts are made on ensuring the intended learning objectives at the existing level are achieved. In view of the existing misconceptions, there is a need to implement an effective and sustainable method for the teaching and learning of secondary school and pre-college physics.

The Use of Concept Mapping in Concept Learning

Concept mapping is a graphical based method that involves a person constructing concept maps as part of the teaching and learning process resulting in one or several concept maps. The concept maps produced is able to show the relationships between the main concept and several other sub-concepts in the domain under study (Novak & Gowin, 1984). Its basic principle is 'the use of simple comprehensive texts containing facts, definitions and principles'. The concept mapping method is a learning method that is grounded in the learning psychology of David Ausubel (Ausubel, Novak & Hanesian, 1978) who proposes that learners learn best when they can link the materials presented to them to their existing knowledge structure. Concept mapping is a tool that helps to accommodate this need – to link existing knowledge to new knowledge.

Efforts undertaken to improve concept learning in physics to date include using technology supported learning system (Albacete & VanLehn, 2000); using innovative teaching approach such as the interactive conceptual instruction approach (Savinainen & Scott, 2002) and using cognitive tools such as concept maps as reported by Zieneddine and Abd-El-Khalick (2001). Among the approaches mentioned here, concept mappings have been widely reported to be providing a sustainable approach that gives good results in developing understanding of concepts in general.

Previous studies indicate that the use of concept maps is useful to learning. Even the act of drawing the map itself can facilitate concept learning as the efforts in trying to construct the concept map forces the person who draws it to confront their pre-conceived ideas and understanding of the concept and to further seek clarifications where necessary (Inman et. al., 1998; Ellis, et. al., 2004). Thus, an internally motivated learning efforts are induced which is intuitively more conducive for learning to occur. Other benefits of concept mappings to teaching and learning include, improved efficiency in notes-taking (Srantesson, 1991), supports collaborative learning efforts (Belbin, 1981; Stäuble, 2005) and aids in memorization and recall (Deschler, 1990) and an increase in the effectiveness of teacher-students communications (Kinchin, 2003; Kinchin & Alias, 2005). Specific to the learning of physics concepts, results of better learning through concept mappings have been reported by Pankratius, (1990); Normah & Tamby Subahan (1997) among others.

Although numerous studies have been conducted on the use of concept mappings in teaching and learning of the sciences including physics, the "producers" of these concept maps have been mostly students. What happen if the producers of the concept maps are teachers? This question arises because in some instances it is easier to use a teacher-generated concept maps as opposed to student-generated concept maps. For example, sometimes students may lack the skills in concept mapping in addition to their limited knowledge of the concepts under considerations. Asking them to construct the concept maps themselves could actually result in additional anxiety, which is not conducive for learning to occur. In such situations, teachers may decide to generate the concept maps themselves. The question of immediate interest here is whether teacher generated concept maps has equally beneficial effect on learning. To date there is relatively little research reported on teacher generated concept map as compared to students generated concept maps except one by Deshler (1990) who proposes that a well constructed concept map is better able at clarifying the relationships between the various elements within a concept compared to textual explanation of the same concept and thus is more efficient at promoting better understanding of concepts.

It is thus imperative to do this study so that the extent to which teacher-generated concept maps influence learning can be assessed. If the finding indicates positive influence of teacher generated concept map, it would be a finding of great practical significance to

teaching and learning as the use of teacher generated concept maps in teaching and learning can be easily implemented.

The main aim of this study was to determine the effects of teacher generated concept maps on students' understanding of linear motion concepts in secondary school physics. The effects of interest were the short-term and the long term learning gains. Knowing the short-term effect is important as it is often used as the indicator of success in teaching. Knowing the long-term effect is equally important because long-term learning gain is more likely to be transferable and applicable to future task demands.

In order to gain a better understanding of how teacher generated concept maps affect learning, it was essential to look at not only the product of teaching and learning (learning gain) but equally important to look at the process of learning, i.e., looking at what transpires in the classrooms during the teaching and learning process. Therefore, it was also one of the objectives of this study to look at how concept mappings affect classroom interactions. Since, perceiving something in a certain light has been known to affect a person's response to the object perceived; knowing students' perception towards the use of concept maps was also thought to be relevant for a better understanding of the effect of concept mapping technique on students' achievements.

Based on the argument above, four research questions were formulated for the study. The research questions were:
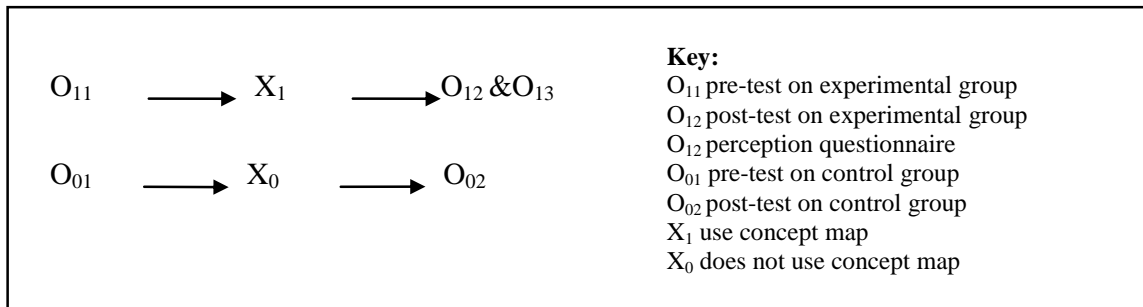
(i) Is there a difference in the short-term learning gain between the group that was taught using concept maps and the group that was taught using the conventional method?

(ii) Is there a difference in the long-term learning gain between the group that was taught using concept maps and the group that was taught using the conventional method?

(iii) What are students' perceptions of the usefulness of concept maps in teaching and learning?

(iv) Is there a difference in the frequency and type of classroom interactions between the group that was taught using concept maps and the group that was taught using the conventional method?

The scope of the study is limited to the effect of concept maps on the learning of six inter-related concepts in linear motion taught in form four physics namely, speed, distance, velocity, displacement, acceleration and deceleration. Form four is year four of secondary school in Malaysia and students are introduced to physics in form four. As a general information, Malaysian education system requires students to attend six years of primary school starting from the age of seven and five years of secondary school.

METHODOLOGY

a) Research Design

The quasi-experimental design method of pre and post-test with a control group was used in the study (Figure 1). The independent variable was teaching method namely, "using or not using concept mapping" and the dependent variable was gain in learning based on the score obtained in the physics achievement tests.

$O_{11} \longrightarrow X_1 \longrightarrow O_{12} \& O_{13}$

$O_{01} \longrightarrow X_0 \longrightarrow O_{02}$

Key:
O_{11} pre-test on experimental group
O_{12} post-test on experimental group
O_{12} perception questionnaire
O_{01} pre-test on control group
O_{02} post-test on control group
X_1 use concept map
X_0 does not use concept map

Figure 1. *Research Design*

b) Sample

The samples for the study were two intact classes of year four secondary school students from the mechanical engineering studies stream at the Teluk Intan Technical School in the mid-western state of Perak, Malaysia. The first class consisted of 28 students and the second class consisted of 29 students. The average age of both classes was 16.6 years old. The Teluk Intan Technical School is one of the 90 technical schools under the Malaysian Ministry of Education. The students from this particular school were chosen as the sample for the study because the researchers had good working relationship with the school administrators ensuring a smooth execution of the study.

c) Data Gathering instruments

Three data gathering instruments were used, a physics achievement test instrument, a perception questionnaire and an observation schedule.

i) Physics Achievement Test

A physics achievement test was used to measure knowledge on physics concepts. The same items were used for the pre-test and post-test. The physics test, which was specifically developed for this study consisted of 20 items, to be answered in forty minutes. The objective of this test was to measure students' knowledge on the concepts of speed, velocity, displacements, distance, acceleration and deceleration. These concepts were chosen because they form the foundation for the learning of more advanced physics concepts later on.

Two response formats were used in the test i.e., choosing the correct answer from a given set of alternatives and giving a free response to test items. The free response format items are not truly "free" as those found in questionnaires. In this study the free response format items are items that require students to provide the answers instead of requiring students to simply select an answer from a set of alternatives. Content validity of the test was achieved through subject matter expert's verifications based on the expert's opinion of an experienced physics teacher in the same school. The reliability of the physics test was estimated using an internal consistency method, the Cronbach alpha method. This method was used as it is most suitable for estimating the reliability of test items that are dichotomously or non-dichotomously scored (Brown, 2002) such as the current physics test. The estimated reliability ($r = .58$) was acceptable in accordance with Rudner and Schafer (2001), who propose that a teacher constructed classroom test with a reliability estimate of 0.5-0.6 is acceptable. Therefore, the test instrument used in this study was considered to be valid and reliable for the purpose of this study. The same physics test was used in the pre and post-test.

ii) Perception Questionnaire

A perception questionnaire was used to gather data on students' perception of the usefulness of concept mappings to teaching and learning. The purpose of the questionnaire was to gather data on students' perceptions on the usefulness of concept maps towards their learning. The questionnaire was specifically developed for the study by the authors. The questionnaire consisted of 14 items and respondents were required to give a rating of their agreement to a given statement on a scale of 1 (strongly disagree) to 5 (strongly agree).

The reliability estimate of the questionnaire based on the Cronbach Alpha method is 0.84, which is consistent with the reliability estimates of perception questionnaires from similar studies (Quek et. al., 2002) who obtained reliability estimates ranging from 0.5-0.9 in their studies.

iii) Observation Schedule

An observation schedule was used to gather data on students' interactions in class. The observation schedule was divided into several sections with each section representing a 10-minutes session of class teaching. Observations were recorded for any actions or non-actions committed by students that indicate either interactions or non-interactions. Some examples of interactions include "asking questions voluntarily", "responding to teacher voluntarily", "interacting with friends", "writing down notes" and "giving opinions voluntarily". An example of a non-interaction is sleeping in class. An assistant was trained to assist with the gathering of the observation data. A video camera was also used to record events to ensure a comprehensive gathering of data during the teaching and learning process.

d) Research Procedures

Both groups of students were given the physics test prior to the intervention. During the intervention, the experimental group ($n = 28$) was taught the chosen physics concepts using concept mappings as a teaching and learning tool while the control group ($n = 29$) was taught the same concepts without concept mappings. Both groups were given 40 minutes instruction on the concepts. Therefore, the main difference between the learning experiences of the two groups was in the use of concept mappings by teacher and students in the experimental group.

In the concept-mapping group, the teacher drew a concept map progressively in line with the progress of the lesson. Students were asked to copy the concept maps drawn by the teacher and were encouraged to expand on the concept map by adding examples of their own. However, students were not asked to independently construct their own concept maps. Therefore, the concept maps were largely teacher generated while the students' role in the teaching and learning process were mainly as users of these concept maps. At the end of the lesson, an overview of the main concepts and its sub-concepts including their propositional links as shown in Figure 2 was produced by the teacher. Translation of the concept map is given in the Appendix.

The same teacher was teaching both groups therefore, teacher differences were not expected to be a source of confounding. Both groups also received a set of identical brief notes prepared in power-point presentations style at the beginning of the lesson. Table 1 illustrates a typical unit of teaching and learning activity. Both groups were administered the post –test after the intervention while only the concept map was asked to answer the perception questionnaire. Video recordings and observations were made on both groups to gather data on the students' interactions in class.

Table 1. *Typical unit of teaching and learning activity*

| Concept mapping group	Non-concept mapping group
• Teacher explains, • Teacher draw map, • Students copy map • Students encouraged to ask, • Students encouraged to expand on the concepts by giving examples, • Students asked to explain using the concept map.	• Teacher explains, • Teacher write notes, • Students copy notes, • Students encouraged to ask, • Students encouraged to give examples to elaborate points, • Students asked to explain.
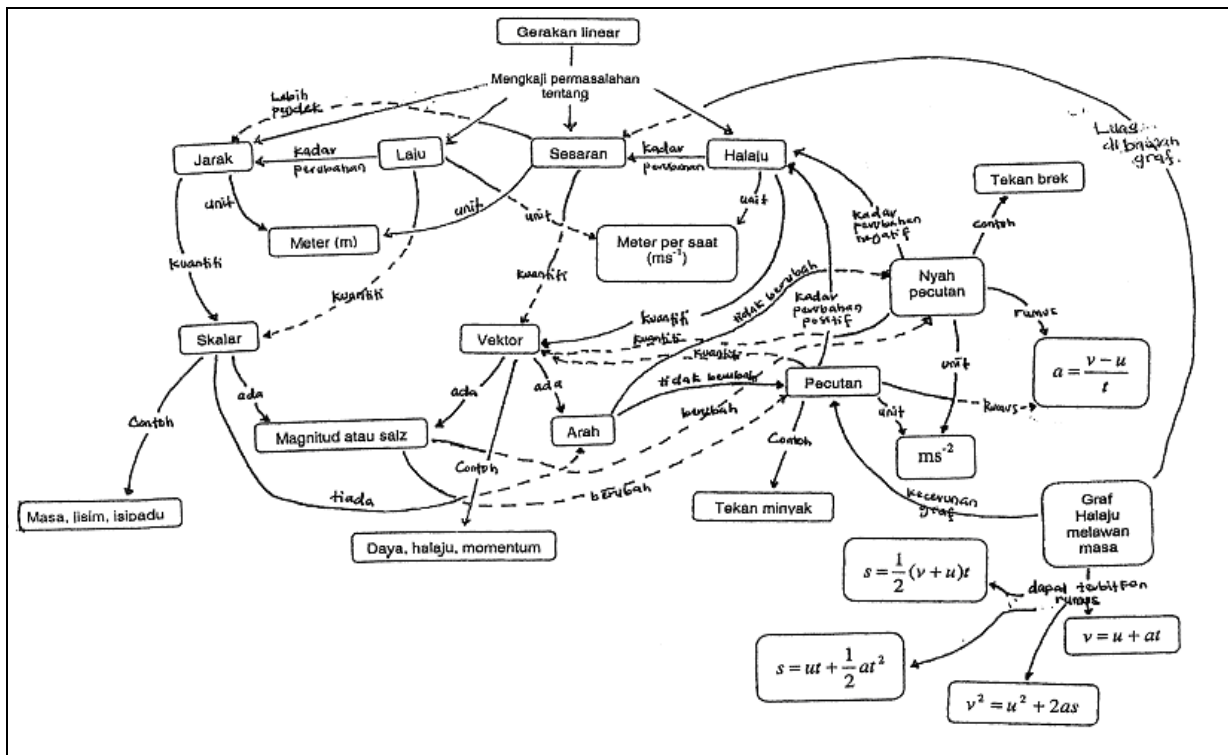
Figure 2. *Teacher generated concept map in Malay Language*

RESULTS and DISCUSSION

Before presenting the results per-se, a check on group equivalence based on the pre-test scores will be shown first, followed by the results on learning gains, perception towards concept maps and classroom interactions. All significance testing was carried out at the 5% level of significance unless stated otherwise and all data analysis activities were carried out using SPSS version 13.

The mean scores on the pre-test were very similar for the two groups as shown by the descriptive statistics in Table 2. As the data were from two independent sources and appear be having equal variances (Levine's test with $p>.05$), the equal variance independent t-test was used to test the equality between the two mean scores that was generated by the two groups. The t-test results indicate that the difference in initial test scores between the two groups is not statistically significant (Table 2). Therefore, the two groups were assumed to be equivalent with respect to their initial knowledge and understanding of linear motion concepts.

Table 2. *Descriptive statistics and t-test results on initial group differences*

Group	Descriptive statistics (Pre-test)		Levine's Test		Independent t-test		
	$\overline{x}$	s	F	p	t	df	p
Experimental group	9.75	3.18	0.14	.905	-0.093	55	.926**
Control group	9.83	3.10					

 **Difference is not statistically significant, *p*>.05

A) Gain in learning from the intervention

Two types of learning gain were investigated, immediate learning gain and long-term learning gain. Learning gain was refers to the gain in scores which were obtained by subtracting the pre-test scores from the post-test scores.

a) Immediate learning gain

Table 3 shows the descriptive statistics and the *t*-test results on the difference in the immediate learning gains. The data were obtained immediately after the intervention. The immediate mean gain score for the experimental group (7.53) is twice as much as the control group (3.12) and the difference is statistically significant at the 5% level of significance (*p*=0.000) based on an equal variance independent t-test. The equal variance independent *t*-test was used after ascertaining that the two groups have similar variances as indicated by the *p*-value for the Levine's test that is greater than .05. The statistically significant difference in the t-test result means that the experimental group obtained larger learning gain compared to the control group suggesting the benefit of teacher generated concept maps on learning.

Table 3. *Descriptive statistics and t-test results for difference in short term learning gains*

Group	Descriptive statistics (Gain score)		Levine's test		Independent t-test		
	$\overline{x}$	s	F	p	t	df	p
Experimental group	7.53	3.12	0.75	0.39	5.31	55	.000*

The effect size of the mean difference, which was computed, based on Bloom (1984) is 1.1. According to Willingham, (2002), an effect size of as low as 0.25 can be considered practically significant and an effect size of above 1.0 is considered exceptional in education research. Clearly, the gain in learning by the experimental group is not only statistically significant but most importantly, it was academically significant. The gain is also practically significant because teacher generated concept maps does not require a lot of resources or efforts to implement.

b) Long-term learning gain

Table 4 shows the mean scores for the long-term gain in learning measured six weeks after the pre-test. The control group experiences a small reduction in their gain score while the experimental group experiences a relatively larger reduction their gain score. Nevertheless, the mean of the long-term gain in learning for the experimental group is still higher than the mean of the control group. An equal variance t-test indicates that the difference is statistically significant at the 5% level of significance.

Table 4. *Descriptive statistics and t-test result for difference in long-term learning gain*

Group	Descriptive statistics (Gain score)		Levine's test		Independent *t*-test		
	$\bar{x}$	s	F	p	t	df	p
Experimental group	4.39	3.201	1.790	0.186	2.08	55	.042*
Control group	2.34	3.143					

*Difference is statistically significant, *p<*.05

Effect size was calculated for the difference and was found to be 0.65, which is comparable to the finding by Rohrer et al., (2005), who obtained an effect size of 0.75 for the impact of over learning. Again, the gain in learning is academically significant in accordance with Willingham (2002) and therefore, it appears that the impact of concept mappings on long-term learning is also commendable.

B) Perception towards the Usefulness of Concept Mappings

Overall rating by students on the usefulness of concept mappings is high, (mean rating = 4.27 out of 5) indicating that students perceive concept maps as a useful tool to their learning. The highest rating is for the item that measures the usefulness of concept mapping in promoting understanding (mean rating = 4.57) which is consistent with the benefit of using concept maps as proposed by Novak and Gowin (1984). The lowest rating is for the two items that asses students' tendency to use concept maps in discussion with teachers, which is 3.75. The result here appears to be contradictory to previous findings that support the positive role of concept mappings in promoting student-teacher discussions (Kinchin, 2003; Kinchin & Alias, 2005). The contradictory finding could be due to the fact that the concept maps in Kinchin and Alias (2005) are students generated which more often than not include elements of misconceptions prompting questions from the teacher who is trying to reduce the misconceptions held by the students. In contrast, the maps in the current study are teacher generated and most probably are already very clear to the students and may not require further clarifications and thus no need for discussions. Since the true reason behind the contradictory finding is currently unknown, further investigation is necessary in order to understand the real underlying causes of the lower rating for these particular items.

C) Class Interactions

Interactions recorded were grouped into six types namely, volunteer to answer, volunteer to ask, interact with friends, volunteer to give opinions, take notes and sleeping. Figure 3 illustrates the frequency of the observed interactions during a 40 minutes lesson on linear motion. A stark difference can be seen in the frequency as well as the type of interactions between the two groups. For the treatment group three positive interactions remain constant namely, taking down notes, volunteer to answer and volunteer to give opinions. While for control group, the same interactions were observed to be diminishing right from the second 10-minutes session and approaching to less than five people. Specifically, the number of students taking down notes in the experimental group is consistent from the first 10 minutes to the fourth while the number in the control group decreases from 29 down to 5 at the end of the 40 minutes lesson. In fact, all types of interactions are decreasing for the control group except for two, interactions with friends and the number of students who sleep. The increase in interactions with friends together with the drop in the number of students taking down notes (negative interactions) is taken to be a strong indicator

of boredom setting in for the control group which is further confirmed by some students in the group falling asleep (even if only two of them). The higher incidences of positive classroom interactions for the concept map group were interpreted as the positive impact of concept mappings on the learning process.
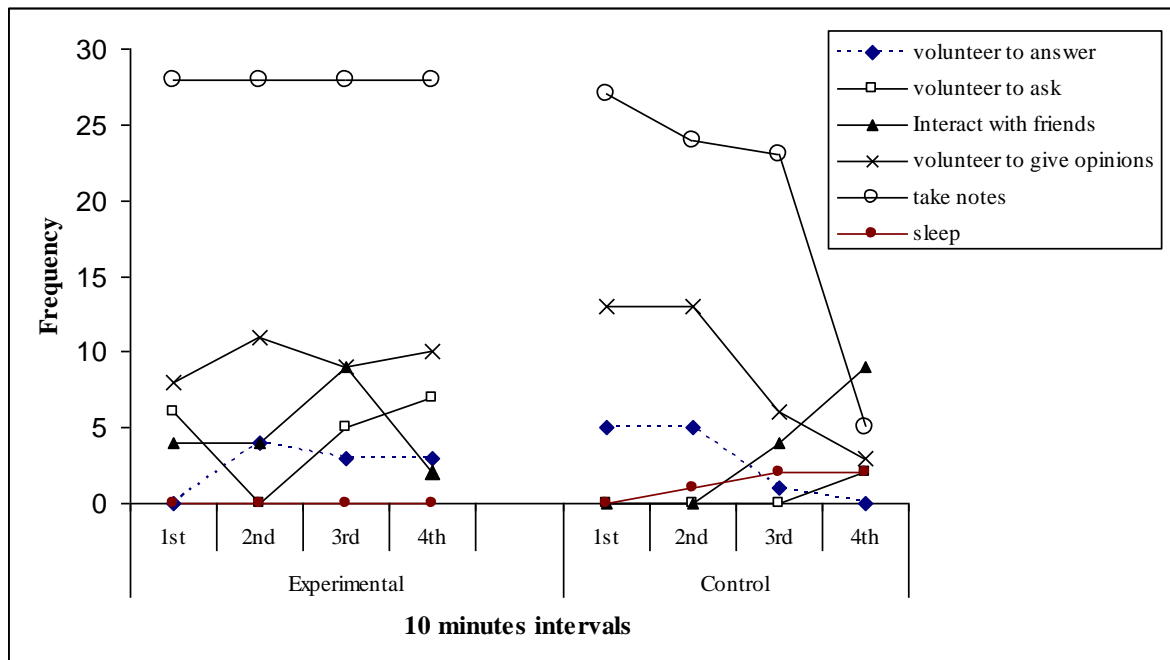

Figure 3. *Frequency distributions of class interactions*

CONCLUSION

This study sets out to determine whether teacher generated concept maps benefit students in the learning of linear motion concepts in secondary school physics. The findings indicate that students do learn better, when concept mappings are used in the teaching and learning of the selected concepts and students do retain more of what they have learnt in the long-term. The positive impact of teacher generated concept maps on both short-term and long-term learning was not only statistically significant but also academically significant. Therefore, serious considerations should be given to the adoption of concept mappings as a teaching and learning tool in the learning of physics even at the level of only the teacher drawing the concept maps. The findings from the study also indicate that the use of concept mappings promotes students-teacher and student-student interactions, support active learning, which is conducive to learning, in general which is a factor contributing to the higher gain in learning.

Students' positive perception towards concept mappings in the current study could also be a factor explaining the positive impact on learning. It is not known however, if the same effect on learning will be found where students taught using concept mappings have negative perceptions of the method. Therefore, future study could be carried out to determine if perceptions towards concept mappings have any bearing on classroom interactions and learning gain. The current findings were limited to teacher generated concept maps. The impact of students generated concept maps on learning gain may not be the same because students' attributes such as concept mapping skills and learning preferences may interact with learning. Studying the interactions between students' skills and preferences towards concept mapping may be the focus of future study.

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Appendix: English Translation of Concept Map