THE EFFECT OF TEACHER GENERATED CONCEPT MAPS ON LEARNING OF SECONDARY SCHOOL PHYSICS

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Abstract. Physics concepts underpin much higher level technical knowledge and therefore are crucial to success in many technical disciplines. However, misconceptions in elementary physics are quite prevalent among secondary school students. Therefore, it is important to identify and implement the most effective teaching and learning methods that can reduce instances of physics misconceptions. The aim of this study was to investigate the effect of using teacher generated concept maps on the learning of linear motion concepts in the secondary schools physics. The study used a pre and post-test quasi-experimental design method with a control group. The samples were two groups of form four students from a Teluk Intan Technical Secondary School in Perak, Malaysia consisting of 28 and 29 students for the experimental and control group respectively. The experimental group was taught physics with concept maps being one of the teaching and learning tools and the control group was taught physics without concept maps. Data were gathered on types and frequency of classroom interactions, students' perception of concept maps and their learning achievements in physics test. It was found that students in the concept mapping group were more participative in class and obtained a statistically significantly higher mean gain on the physics test ($\mu=17.3$) compared to the non-concept mapping class ($\mu=12.9$) with $p < 0.001$. The concept mapping group also performed better on the long-term achievement measure. It was concluded that teacher generated concept maps is an effective teaching and learning tool for promoting concept learning of linear motion in physics.

Category Full Paper

1 Introduction

Having knowledge and deep understanding of physics is important especially for those who intend to pursue a career in the technical disciplines such as engineering. Unfortunately misconceptions in physic are quite common among students (Palmer, 1998). These misconceptions usually persist to interfere with students' ability to master subsequent concepts that they need to learn at higher level (Halloun & Hestenes, 1985). Remediation when the students are at higher level can be time and effort consuming not only on the part of the students but also the teacher. The time and efforts allocated for remediation could be better used for acquiring the intended objectives for that level. Therefore, more effective methods need to be identified and used in the teaching and learning of secondary school and pre-college physics.

Efforts undertaken to improve concept learning in physics include using technology supported learning system (Albacete & VanLehn, 2000); innovative teaching approach such as the interactive conceptual instruction approach (Savinainen & Scott, 2002) and cognitive tools such as concept maps (Zieneddine & Abd-El-Khalick, 2001). Among the approaches mentioned here, concept mappings have been widely reported for purportedly giving good results in developing understanding of concepts in general. A concept map is a graphical based method that shows the relationships between the main concept and several others sub-concepts (Novak & Gowin, 1984). Its basic principle is 'the use of simple comprehensive texts containing facts, definitions and principles'. A concept map is said to be able to clarify the relationships between the various elements within a concept (Deshler, 1990). Some literature indicated that the act of drawing the map itself forces the person who draws it to confront his pre-conceived ideas and understanding of a concept and to seek clarifications where necessary (Inman, Ditson & Ditson, 1998; Ellis, Al Rudnitsky & Silverstein, 2004).

Other reported benefits of concept maps to teaching and learning in general include, increase effectiveness of teacher-students communication (Kinchin, 2003; Kinchin & Alias, 2005), improved efficiency in notes-taking (Srantesson, 1991) supports collaborative learning efforts (Belbin, 1981 & Stäuble, 2005) and aids in memorization and recall (Deschler, 1990). Specific to learning in physics, results of better learning through concept maps have been reported by Pankratius, (1990); Normah & Tamby Subahan (1997) among others. Most of these studies however, were looking at the effect of students generated concept maps on learning. The effect of teacher generated concept maps has been less studied. Knowing the extent to which teacher generated concept map can influence learning is important because teacher generated maps is easily implemented and therefore can be of academic significance and practical significance.

1.1 *Purpose of study*

The main purpose of the study was to determine the effects (short-term and long-term) of teacher generated concept maps on students' understanding of physics concepts. In order to have a better understanding of how using concept maps may affect learning, it was also important to look at both the product (learning gain) and the process of learning itself, i.e., looking at what happens in the classrooms during the teaching and learning process. Therefore, it was also the aim of this study to look at how using concept maps 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. Four research questions were formulated for the study. The research questions are:-

(i)   Is there a difference in the short-term learning gain between the group that does and the group that does not use concept maps?

(ii) Is there a difference in the long-term learning gain between the group that does and the group that does not use concept maps?

(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 does and the group that does not use concept maps?

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. Only manually constructed concept maps in Bahasa Melayu were used in the study.

2   Research Methods

To answer the first and second research questions, the quasi-experimental design method of pre and post test with a control group was used. The research design is shown in Figure 1. The independent variable is "using or not using concept map" and the dependent variable was score on the physics achievement test. The participants for the study were two intact classes of form four mechanical engineering studies students from Teluk Intan Technical Secondary School located in Perak, Malaysia. The topic chosen was linear motion which is one of the earlier topics taught in form four physics. Mastering the concepts within this topic is important as they form the basis for learning of more advanced topics later on.
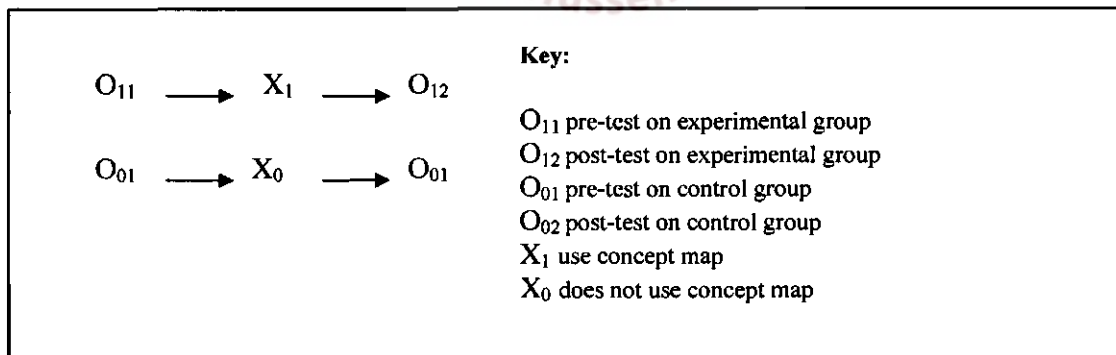
$$O_{11} \longrightarrow X_1 \longrightarrow O_{12}$$

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

Key:

O_{11} pre-test on experimental group

O_{12} post-test on experimental group

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 for the study

Three data gathering instruments were used, (i) a physics achievement test, (ii) an observation schedule and (ii) a questionnaire. The achievement test consisted of 20 items to be answered in forty minutes. The objective was to measure knowledge on concepts of speed, velocity, displacements, distance, acceleration and deceleration. Two response formats were used i.e., choosing from given alternatives and free response style. Content validity was achieved through subject matter expert's verifications based on the expert opinion of an experienced physics teacher in the school. The reliability estimate based on the Cronbach alpha method was 0.58. The estimated reliability was

acceptable in accordance with Rudner & Schafer (2001), two measurement experts who state that a teacher developed 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 adequately reliable for the purpose of this study.

The perception questionnaire was used to gather data on students' perception of the usefulness of concept maps to teaching and learning. It consisted of 14 items that requires the participants to give a rating of their agreements to a given statements on a scale of 1 (strongly disagree) to 5 (strongly agree). The reliability estimate based on the Cronbach alpha method is 0.84, which is consistent with reliability estimates of perception questionnaires from other such studies (Quek, Wong & Fraser, 2002) who obtained reliability estimates ranging from 0.5-0.9.

The observation schedule was used to gather data on class interactions. The schedule is divided into sections. Each section represents a 10 minutes session of class teaching. Observations were recorded for any actions by students that indicate interactions or non-interactions such as asking questions voluntarily, responding voluntarily, interacting with friends, writing down notes, giving opinions freely and sleeping in class. An assistant was trained to help with the gathering of the observation data. A video camera was also used to record events during the teaching and learning process.

2.1 Procedures

Pre-test on physics were given to both groups prior to the intervention. During the intervention, the experimental group was taught the chosen physics concepts using concept maps as a teaching and learning tool while the control group was taught the same concepts without concept maps. In other words, the main difference between the learning experiences of the two groups was in the use of concept maps by teacher and students in the experimental group. A concept map was drawn progressively by the teacher in line with the progress of the lesson. At the end of the lesson, an overview of the main concept and its sub-concepts including their propositional links as shown in Figure 2 was produced. Translation of the concept map is given in the Appendix.
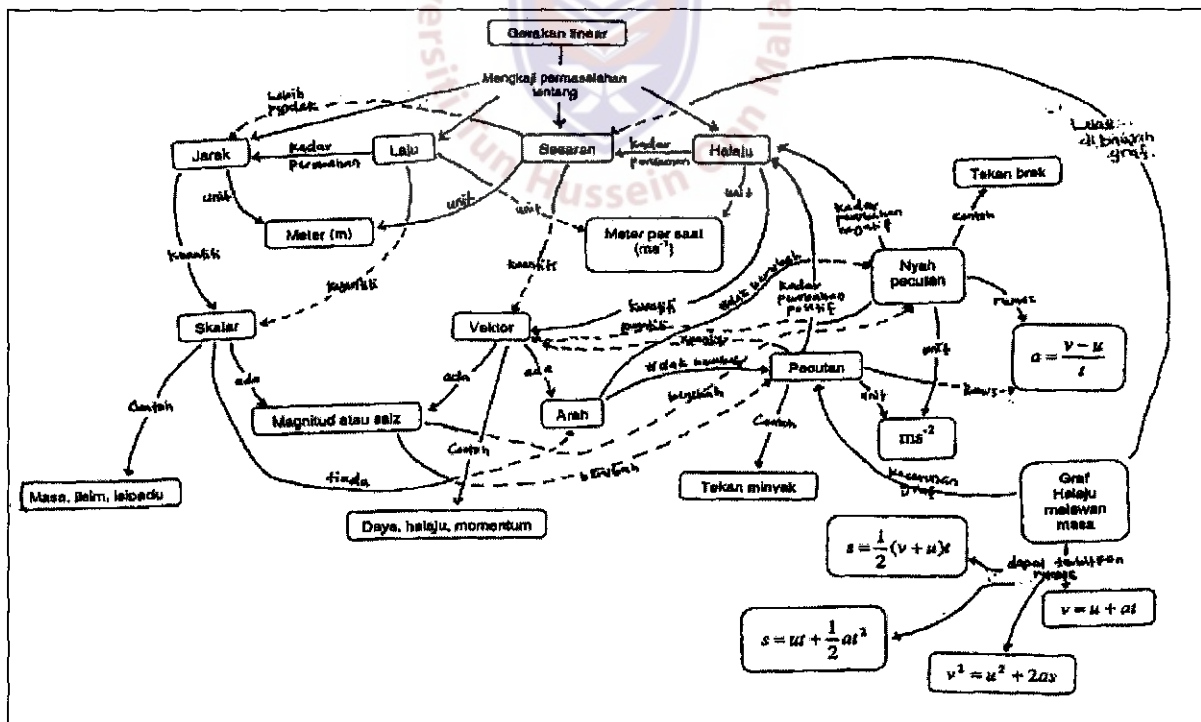

Figure 2: Teacher generated concept map in Bahasa Melayu (Malay Language)

Both groups were taught by one teacher, therefore, teacher differences was not a source of confounding. Both groups also received a set of identical brief notes prepared in power-point presentations style. Both groups were given post –test after the class. Table 1 illustrates a typical unit of teaching and learning activity.

Table 1: Typical unit of teaching and learning activity

Concept map group	Non-concept map 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

3 Results and discussions

Before presenting the results per-se, a check on group equivalence based on the pre-test scores will be shown first to be followed by the results on learning gains, perception towards concept maps and classroom interactions. The mean scores μ on the pre-test were very similar for the two groups as shown by the descriptive statistics in Table 2. Having confirmed equal groups' variances (Levine's test with $p>.05$), comparison between the mean scores was carried out using an equal variance t-test. The t-test results showed that the difference was 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		Levine's Test		Independent t-test		
	μ	s	F	p	t	df	p
Experiment	9.75	3.18	0.14	0.905	-0.093	55	0.926**
Control	9.83	3.10					

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

3.1 Learning gains

Two types of learning gain were investigated, immediate and long-term. Table 3 shows the descriptive statistics and the t-test results on difference in learning gains. The data were obtained immediately after the intervention and therefore this is considered as the immediate learning gain. The immediate mean gain score (μ) for the experimental group ($\mu=7.53$) is twice as much as the control group ($\mu=3.03$) 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 0.05. 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 learning gains

Group	Descriptive statistics		Levine's test		Independent t-test		
	μ	s	F	p	t	df	p
Experiment	7.53	3.12	0.75	0.39	5.31	55	0.000*
Control	3.03	3.32					

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

The effect size of the difference based on Bloom (1984) was computed as 1.1. According to Willingham, (2002), an effect size of as low as 0.25 can be considered practically significant and 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 and practically significant indeed.

Table 4 shows the means for long-term gain measured six weeks after the pre-test. The control group experienced only a small drop while the experimental group experiences a big drop in long-term gain. Nevertheless, the mean in long-term gain of the experimental group is still larger than the mean of the control group. An equal variance t-test indicated that the difference was statistically significant at the 5% level of significance.

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

	Descriptive statistics		Levine's test		Independent t-test		
Group	μ	s	F	p	t	df	p
Experiment	4.39	3.201	1.790	0.186	2.08	55	0.042*
Control	2.34	3.143					

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

Effect size obtained for the difference was 0.65 which is comparable to a study on long-term gain by Rohrer, *et al.* (2005) who obtained an effect size of 0.75 in a study on the impact of over learning. Again, the gain is practically significant in accordance with Willingham (2002) and therefore, it appears that the impact of concept map on long term learning is also commendable. All data analysis results were based on SPSS version 13.

3.2 Perception towards the usefulness of concept maps

Overall rating by students on the usefulness of concept maps was high, (μ = 4.27) indicating that students perceive concept maps as a useful tool to their learning. The highest rating was for the item that measures the usefulness of concept map in promoting understanding (μ= 4.57) which is consistent with the benefit of using concept maps as proposed by Novak & 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 in contradiction to previous findings that support the positive role of concept maps in promoting discussion (Kinchin, 2003 and Kinchin & Alias, 2005). However, in the case of Kinchin and Alias (2005) the maps were students' generated and the questions were from the teacher who was trying to reduce misconceptions in the students. On the other hand, the maps in the current study were teacher generated and therefore most probably very clear to the students and therefore did not require many discussions. Further investigation is required in order to understand the real underlying causes of the lower rating for these particular items.

3.3 Class interactions

Figure 3 illustrates the type of interactions and frequency observed during a 40 minutes lesson on linear motion. From the graph, it can be seen that there are differences between the two groups. For example, 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 maps on the learning process.
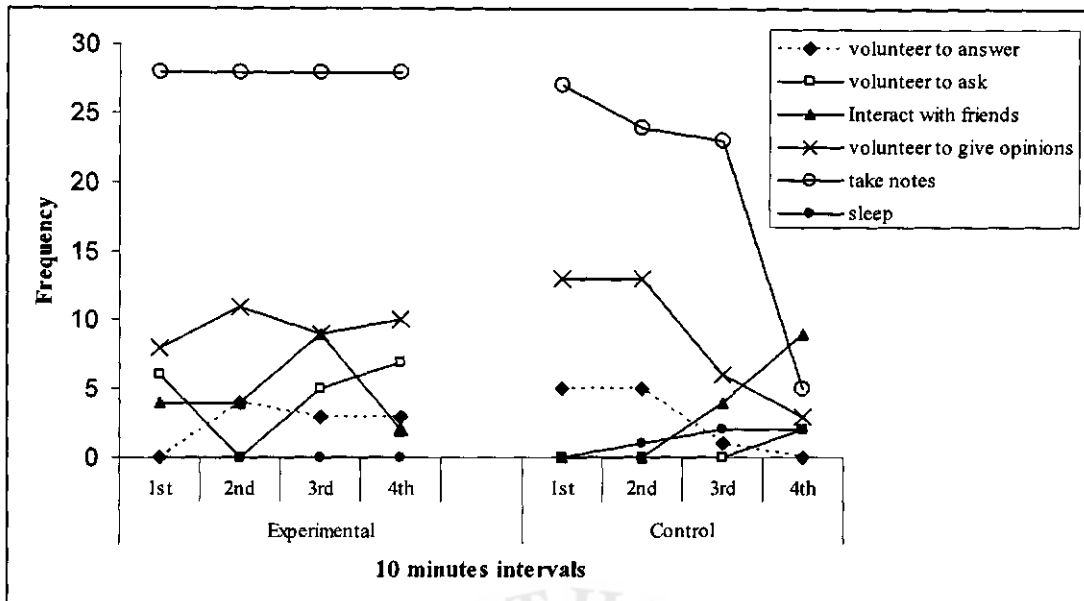
Figure 3: Distributions of class interactions

4 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 maps are used in the teaching and learning of the 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 maps 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 maps promotes students-teacher and student-student interactions supporting 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 maps 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 maps have negative perceptions of concept maps. Therefore, future study could be carried out to determine if perceptions of concept maps 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 teacher generated concept map

LINEAR MOTION

- LINEAR MOTION —a study on problems related to→ Displacements
- LINEAR MOTION —→ Distance
- LINEAR MOTION —→ Velocity
- LINEAR MOTION —area under→ Velocity-time graph
- Distance —may be shorter than→ Distance
- Speed —rate of change of→ Distance
- Displacements —rate of change of→ Velocity
- Velocity —-ve rate of change of→ Deceleration
- Braking —example→ Deceleration
- Distance —has unit→ Meter (m)
- Speed —has unit→ Meter (m)
- Displacements —has unit→ Meter (m)
- Velocity —has unit→ meter/s
- Distance —is→ a scalar quantity
- Speed —is→ a scalar quantity
- Displacements —is→ a vector quantity
- Velocity —is→ a vector quantity
- Acceleration —is→ a vector quantity
- +ve rate of change
- Deceleration —is negative→ Acceleration
- Deceleration —has formulae→ a=(v-u)/t
- Deceleration —has unit→ m/s/s
- Acceleration —has unit→ m/s/s
- Acceleration —has formula→ a=(v-u)/t
- a scalar quantity —for example→ Time, mass, volume
- a scalar quantity —has→ Magnitude or size
- a vector quantity —has→ Direction
- a vector quantity —examples are→ Force, speed and momdentum
- Acceleration —does not change for→ Direction
- Acceleration —does not change for→ Magnitude or size
- Direction —example→ Press accelerator
- a scalar quantity —has no→ Direction
- Magnitude or size —changes for→ s=1/2(v+u)t
- Direction —changes for→ Magnitude or size
- Velocity-time graph —slope is→ Acceleration
- Velocity-time graph —yield→ s=1/2(v+u)t
- Velocity-time graph —yield→ v=u+at
- Velocity-time graph —yield→ s=ut+1/2at^2
- Velocity-time graph —yield→ v^2=u^2+2as