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THE EFFECTS OF THINKING MAPS-AIDED PROBLEM-BASED LEARNING ON MOTIVATION TOWARDS SCIENCE LEARNING AMONG FIFTH GRADERS

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Abstract. *This research was conducted to evaluate the effects of Thinking Maps (TM)-aided Problem-based Learning (PBL) teaching method (TM-PBL) on motivation towards science learning among Fifth Graders. A quasi-experimental pre-test/post-test non-equivalent control group design was employed to measure students' motivation towards science learning (SMTSL) in motivational factors of self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The sample consisted of 270 Fifth Graders aged 11 years old. The students were randomly selected and assigned to TM-PBL (n=90), PBL (n=90), and Conventional Problem Solving (CPS) (n=90) teaching groups. The SMTSL questionnaire was administered prior to and after each intervention. A MANCOVA was conducted on the post-test measures of motivation using the students' pre-test as the covariates. The result indicated that students taught via the TM-PBL teaching method gained significantly higher levels than their counterparts from the PBL group in Self-efficacy, Active learning strategies, Achievement Goal and Learning environment stimulation. Likewise, students taught via the TM-PBL teaching method gained significantly higher levels than their counterparts from the CPS group in all motivational factors. The findings suggest that the Thinking Maps-aided Problem-Based Learning method is effective in improving motivation towards science learning among Fifth Graders.*

Keywords: *fifth graders, motivation towards science learning, problem-based learning, thinking maps.*

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Introduction

Motivation has several effects on students' learning, cognitive processes and performance. Students' motivation in learning specific subject content areas such as in science has been shown to positively influence students' conceptual change processes (Lee, 1989; Lee & Brophy, 1996; Pintrich, Marx, & Boyle, 1993), and science learning achievement (Napier & Riley, 1985). Motivation towards learning is the driving force that can stimulate, maintain and control students' attention on the acquisition and understanding of knowledge (Pintrich & Schunk, 2002).

Despite the recognition given to the importance of motivation towards learning, there is little evidence to demonstrate researches conducted in Malaysia on students' motivation towards science learning in primary schools. In a study to evaluate Grade 10 students' motivation, it was discovered that Problem-Based Learning (PBL) had a significant impact on students' motivational factors in biology learning value, targeted behavior, and learning environment stimulation (Shamsuddin, 2007). As the study involved only Grade 10 students and measured just three motivational factors, further research needs to be undertaken with a broader scope that focuses on lower-age groups and assess more motivational factors. In affiliated researches done using contextual learning in learning physics (Samsudin, Md Zain & Ismail, 2003) and advance organizers in learning Biology (Shihusa & Keraro, 2009), where significant differences in motivation were revealed between the experimental and control group, no details were given as to which motivational factor might have contributed to the students' motivation towards learning. A lack of attention to motivation in the design of effective instruction for primary schools can lead to the decline in motivation towards science learning among young students. Hence, it is important to investigate specific teaching methods that can contribute to the development of a broader range of motivational factors in primary school science lessons.

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Learning Environment for Developing Motivation towards Science Learning

According to Cetin-Dindar (2012), Banchi and Bell (2008), and Yager (2000), a constructivist learning environment is conducive for the development of motivation towards science learning. They argued that in a constructivist learning environment, students are encouraged to practice thoughtful reflection on experience, learn to analyze real world issues, learn how to investigate, be enhanced in social negotiation, develop their collaborative learning and inquiry skills, build communication skills, improve their learning strategies skills, and reach a collective outcome over a period of time. When the principles and processes of PBL are examined, it becomes apparent that PBL covers the needs of motivation for learning. PBL embodies the principle that learning begins with analyzing and solving real-world problems (Barrett & Moore, 2012; Savin-Baden, 2004), for which the students' world of experience is connected (Graaff & Kolmos, 2003). Once students find the relevance of science problems with daily life experiences, their motivation is aroused. They can then believe in their own ability to investigate and solve a given science problem. PBL engages students to take an active role in group discussion (Etherington, 2011; Van Blankenstein, 2011) using a variety of learning strategies (Ngeow & Kong, 2001). Willingness to participate and make decisions in group discussion enables students to gain ownership of the task (Etherington, 2011) necessary for enhancing students' motivation towards learning.

PBL also encourages students to work in collaborative groups under the guidance of a teacher and share their own thoughts and views freely among group members (Barrows, 1996; Tatar & Oktay, 2011; Droha, Mauffette, & Allard, 2012). PBL creates a supportive learning community and sustains interaction that explicitly scaffolds learners to learn within social constructivist paradigms, both for the teacher and the student (Cochrane, 2012, p. 125). This PBL philosophy in developing a supportive learning environment bears the possibility of fulfilling students' needs which influences their motivation in science learning. Thus, it can be posited that PBL creates a conducive environment for motivating students to learn. Indeed, PBL has been identified as influential in promoting students' motivation in learning (Barrows, 1986; Hmelo-Silver, 2004; Norman & Schmidt, 1992).

Effects of PBL on Students' Motivation towards Science Learning

As acclaimed by scholars (Norman & Schmidt, 1992; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009). PBL intends to help students to become intrinsically motivated and autonomous learners. Several studies with pre-test and post-test designs have found the positive effects of PBL interventions on school students' self-efficacy beliefs (Brown, Lawless, & Boyer, 2013; Liu, Hsieh, Cho, & Schallert, 2006) while other studies have found positive effects of a PBL learning environment on students' perceptions of task or learning values (i.e., interest, importance, and utility) (Sungur & Tekkaya, 2006). PBL intervention studies have also reported positive impact on students' intrinsic goal orientation (i.e., preference for challenging assignments, interest, and a preference for figuring out problems on their own) (Sunger & Tekkaya, 2006; Pedersen, 2003). Thus, prior studies demonstrated that PBL interventions can enhance students' self-efficacy beliefs and intrinsic motivation.

Despite claims about the positive effect of PBL on students' motivation towards learning, empirical evidence of the advantages of PBL on Malaysian students' motivation towards science learning in primary school education is inadequate. In a meta-analysis conducted by Mustaffa and Ismail (2014) from 2009-2014, there is relatively little research done on the effects of PBL on young learners at the Malaysian primary science level. Several other research studies found positive effects of PBL on motivation in learning calculus (Ahmad Tarmizi, Mokhtar, Mohd Ayub, & Nawawi, 2013) and chemistry (Ismail, 2009) among university undergraduates and Grade 10 school students while additional studies found positive effects of PBL on primary school students' motivation in learning the Living Skills subject (Jasman, 2014). As yet, little is known on the positive effects of PBL on students' motivation towards science learning at the primary school level. Accordingly, it is imperative that research be carried out to examine whether PBL enhances students' motivation towards science learning among Malaysian primary school students.

Peterson (1997) stated that the success of PBL depends to a large extent on how well students work together to solve problems. Even though group work is an essential component of learning and teaching in PBL, teachers and students continue to experience difficulties related to working with and in groups (Murray-Harvey, Pourshafie, & Reyes, 2013; Pfaff & Huddleston, 2003; Holen, 2000). Peterson (1997) asserted that students in groups who employed a structured problem-solving process by utilizing a common set of procedures for thinking, have shown improvements in critical thinking, interpersonal skills, problem solving, and learning. Other researchers discovered that the proficient use of thinking tools as a set of thinking procedures can potentially lead to higher levels of self-efficacy and self-regulation, both of which can produce higher levels of motivation to learn (Chularut & DeBacker, 2004; Trifone, 2006). In relation, Then (2014) identified that fourth graders' motivation was enhanced in thinking maps classroom. Thinking Maps are visual representations of thinking tools that help students see their own learning pathway or the thought processes utilized to solve a problem (Alikhan, 2014). These findings raise the question, "To what extent does thinking maps help problem-based learning enhance students' motivation towards science learning?" Tackling such a question, particularly in primary school settings often requires utilizing a specific learning strategy which allows science teachers to seamlessly examine primary school students' extent of motivation towards science learning.

David Hyerle (1996) reported numerous favourable episodes of utilizing Thinking Maps by infusing them into the curriculum. It had helped the students to successfully develop their thinking processes and motivation to learn. Consequently, this research employed an infusion approach where thinking maps are infused with PBL in a primary science lesson and given the name, "Thinking Maps-aided Problem-Based Learning" (TM-PBL). In this teaching method, students are taught explicitly to generate skillful thinking through thinking maps (teaching *about* thinking), and then prompted to use thinking maps to think about the science content they were learning through PBL (teaching *for* thinking). In this research, a thorough infusion was applied, where PBL and Thinking Maps were performed simultaneously along the process of science learning. Thus, this research endeavored to examine the effects of TM-PBL on primary students' motivation towards science learning.

The Theoretical Framework for Motivation towards Science Learning

The motivation towards science learning in this research is based on the theories of constructivism, motivation and expectancy-value. In Vroom's Expectancy-Value theory (Vroom, 1964), "effort" is identified as the major measurable motivational outcome. For effort to occur, a person must: (1) value the task and (2) believe he or she can succeed in the task (Hodson, 1998; Small, 2000). Likewise, according to the constructivist view towards science learning, students take an active role in constructing new knowledge (Mintzes, Wandersee, & Novak, 1998; von Glasersfeld, 1998). When students perceive value and meaning in the learning tasks, they will actively engage in linking their existing knowledge with new experience using active learning strategies. Linking to that statement, motivational theory explicates that 'Motivation is the process whereby goal-directed activity is instigated and sustained' (Pintrich & Schunk, 1996, p. 5). Consequently, according to Pintrich *et al*., (1993), in addition to values of science learning, students' learning goals and self-efficacy also play important roles in influencing students in constructing and reconstructing their science conceptions. In other words, when students perceive that they are capable and that their learning tasks are worthwhile to participate in, and the learning goal is to gain competence, then students will be willing to make a sustained effort and be engaged in the learning tasks and making conceptual change. In addition, Brophy (1998), and Pintrich and Schunk (1996) stress that the learning environment such as teachers' teaching strategies, class activities, and student–teacher and student–student interactions influence an individual's motivation to learn. Based on the theories above, Tuan, Chin, and Shieh (2005) developed the Students' Motivation towards Science Learning Questionnaire (SMTSL) consisting of self-efficacy, science learning value, active learning strategies, learning goal, and learning environment, all of which were the motivational factors investigated in this study.

Research Purpose and Hypotheses

Past studies indicate that students gain most in their motivation towards learning when PBL is utilized in their learning process. In connection, a number of studies give evidence that students' motivation is cultivated when Thinking Maps (TM) are infused into the learning activities. Previous research has also shown that TM is most likely to encourage students to go through the process of self-regulation and develop more motivation to learn. It appears that TM can be infused into PBL to enhance motivation towards science learning such as self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. As yet, little is known on the positive effects of this infusion approach on the subject-specific learning aspects of motivation at the primary school level. Thus, the overall goal of the present research is to find out the extent to which the TM-PBL teaching method would foster students' motivation towards science learning.

This research, therefore, tested the "Infusion Approach" hypothesis against the "Non-Infusion" approach hypothesis by employing the TM-PBL and PBL teaching method to investigate how far these interventions facilitate

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students' motivation towards science learning within a TM-PBL and PBL environment. In addition, the research explored the extent to which the TM-PBL and PBL teaching method affected motivation towards science learning compared to the Conventional Problem Solving method (CPS). Thus, three teaching methods were employed in this research: the TM-PBL, PBL and CPS method. Accordingly, the following hypotheses were postulated:

1. Students taught via the TM-PBL teaching method will gain a significantly higher level than students taught via the PBL in motivation towards science learning in terms of i) self-efficacy, ii) active learning strategies, iii) science learning value, iv) performance goal, v) achievement goal, and vi) learning environment stimulation.
2. Students taught via the TM-PBL teaching method will gain a significantly higher level than students taught via the CPS teaching method, in motivation towards science learning in terms of i) self-efficacy, ii) active learning strategies, iii) science learning value, iv) performance goal, v) achievement goal, and vi) learning environment stimulation.
3. Students taught via the PBL teaching method will gain a significantly higher level than students taught via CPS teaching method in motivation towards science learning in terms of i) self- efficacy, ii) active learning strategies, iii) science learning value, iv) performance goal, v) achievement goal, and vi) learning environment stimulation.

This research focused on comparisons between two different forms of the PBL teaching method, as well as comparisons with the Conventional Problem Solving teaching method in order to determine if other modes of PBL were equally effective in producing desired outcomes. Consequently, this research was conducted to determine whether there were any significant differences in the degree of motivation towards science learning between learners who were taught under the employment of three different teaching methods.

In regards to this research, an operational definition of six motivational factors of motivation towards science learning is stated below:

1. *Self-efficacy*. Students believe in their own ability to accomplish science learning tasks, such as understanding physical science content and concepts, answering science critical thinking tests, and solving science problems.
2. *Active learning strategies*. Students take an active role in using a variety of strategies to construct new knowledge based on their previous understanding.
3. *Science learning value*. Students perceive the values of science learning they engage, such as problem-solving, doing an inquiry or investigation, thinking, and finding the relevance of science with daily life.
4. *Performance goal*. The students' goal in science learning is to compete with other students and get attention from the teacher.
5. *Achievement goal*. Students feel satisfaction as they increase their competence and achievement during science learning.
6. *Learning environment stimulation*. In the class, the learning environment surrounding students, such as teacher' teaching methods and facilitation, and student interaction during science activities influence students' motivation towards science learning.

The three thinking maps used to measure students' critical thinking were a) Double Bubble Map; b) Flow Map; and c) Multi-Flow Map. As stated by Hyerle and Yeager (2007), Double Bubble Maps highlights the "Comparing and Contrasting" thinking process; Flow Maps highlight the "Sequencing" thinking process while the Multi-Flow Maps highlight the "Analyzing Cause and Effect" thinking process.

Methodology of Research

Research Design

The research employed a quasi-experimental pre-test/post-test non-equivalent control group design to examine the effects of three different teaching methods in the process of teaching and learning on Fifth Graders' motivation towards science learning. The independent variable was the three teaching methods: the TM-PBL (treatment 1), PBL (treatment 2), and CPS (control group). The dependent variables were the students' motivation towards science learning in self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The Students' Motivation Towards Science Learning (SMTSL) questionnaire was used as a pre-test and post-test in treatment groups and control groups prior to the start of the intervention and after the 18-hours intervention. This research is limited by its quantitative approach. Despite this limitation, the researcher used it because it captured large sample size which elicited the views of Fifth Graders on the effects of three teaching methods on their motivation towards science learning.

Research Sample

The research population consisted of 4,530 Fifth Graders from 59 primary schools in Tawau, Sabah, Malaysia (Tawau District Education Office, 2015). This research was conducted in September and October 2015 with Fifth Graders in three fully government-funded urban primary schools in Tawau. The three schools were selected based on the similar pre-test mean score gained by its students in the pre- critical thinking test. The three urban schools were selected to reduce the demographic differences among the research samples. A total of 270 students were involved, with 90 students selected from each school, with the consent of Tawau District Education Office, the school principals and class teachers. Students comprised of 141 (52 %) females and 129 (48 %) males aged 11 years old. The three classes in the selected schools were randomly assigned to one of the conditions as intact groups: the TM-PBL method, PBL method, or the CPS method. All 270 students participated in the experimental research within the same week, but at different class schedules for a period of nine weeks. Prior to conducting of the research, participants read and signed the informed consent forms. Participants were given pseudonyms in order to hide their identities. In addition, the students were made aware that they have the right to withdraw from the research at any time without being penalised.

Research Instrument

The effects of the experimental treatments were assessed using a questionnaire termed as Students' Motivation Towards Science Learning (SMTSL) developed by Tuan *et al.* (2005). The SMTSL questionnaire consisted of 35 items with 5-point Likert-type scale responses from Strongly Agree (5) to Strongly Disagree (1). SMTSL is composed of six motivational factors: Self-efficacy (SE), Active Learning Strategies (ALS), Science Learning Value (SLV), Performance Goal (PG), Achievement Goal (AG), and Learning Environment Stimulation (LES). The SMTSL was translated into the Malay language using the back to back translation method with the help of two experts who hold a doctorate and a master's degree in English and Malay language. The 35-item SMTSL was administered to 30 Fifth Graders in a pilot study and was found to have a relatively high Cronbach Alpha reliability value of 0.90 with .74, .76, .70, .72, .70 and .73 for self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation, respectively.

Each questionnaire item required half a minute to complete and the whole SMTSL would take 15-20 minutes. The same SMTSL was used as a pre-questionnaire and post-questionnaire in treatment groups and control groups prior to the start of the intervention and after the intervention.

The Implementation of the Teaching Methods

TM-PBL

The TM-PBL learning module was developed using Fogarty's (1997) Problem-Based Learning model which was found to have high reliability and validity (Mapeala & Siew, 2016). There are eight steps in Fogarty's (1997) problem-based learning model: (1) Recognizing the problem, (2) Defining the problem, (3) Triggering ideas through questions, (4) Forwarding the hypothesis, (5) Conducting research, (6) Reviewing the best solution, (7) Choosing the best solution, and (8) Presenting the solution.

The TM-PBL learning module consisted of 18 learning activities that studied Energy, one of the Physical Science topics in the Fifth Grade Primary Science Curriculum. Each learning activity would take about 60 minutes to complete. The science problems posed in the learning activities were real-life problems and relevant to the daily lives of the students related to energy. In this way, students could find the relation of science with their daily lives, and the values of science learning.

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One sample of the learning activities related to the problem was: "*Based on the views given by an expert about our excessive dependence on non-renewable sources of energy and its impact on the environment in the article above, discuss with your group members about the similarities and differences of two types of energy pointed out by the expert and present it using an appropriate thinking map*".

Students were prompted to make extensive use of Double Bubble Maps, Flow Maps, and Multi-Flow Maps to think about the solution of given ill structured energy-related problems. It was through this process that students would gain benefit from the explicitness of the thinking maps that guide, direct, and stimulate their thinking skills as well as acquiring problem-solving competency. Additionally, the Flow Map with sub-sequence proposed by Hyerle and Alper (2011) was also introduced in the activities. Students had to explain briefly the reason the sequence was made by providing reasons or arguments. In order to stimulate students' motivation in science learning, the teacher acted as a facilitator to allow for discussion and encourage a less rigid thought process.

The TM-PBL activities were conducted in groups of four to five students. The learning activities were color printed on A3 size papers. With these papers, all the group members had an equal opportunity to create and expand their own thinking maps using the same activity sheets. In order to establish a meaningful discussion, students were encouraged to share their thoughts and views with one another, raised questions and entertained viewpoints from peers and facilitators. Through this way, students would take an active role in using a variety of learning strategies to construct new knowledge based on their previous understanding. With the help of more capable peers and thinking maps, students developed their self-efficacy to perform well in the given learning tasks.

After a group presentation of the students' thinking maps to the entire class, the teacher pointed out the unique ideas from each group and praised their good efforts. This kind of supplementary activity increases students' performance goals as they gain attention from the teacher and compete with other groups. Likewise, students' satisfaction would be enhanced as they achieve their achievement goal during the learning of science.

Students were also urged to show respect towards other students' views and support each other during group discussion. This process enabled a trusting and supportive learning environment to be developed in stimulating students' motivation in science learning. Prior to the start of the intervention, the students of the TM-PBL group learned first-hand experience about the three types of TM. They created TM under the facilitation of their teachers. Students were also taught how to behave appropriately in a group discussion. During the intervention, students in their groups created their own TM to solve the given problem.

By employing the TM-PBL teaching method, it was believed that students' motivation towards science learning could be increased.

PBL

The students taught in the PBL group undertook similar learning activities as their counterparts in the TM-PBL group but were not exposed to the Thinking Maps. In groups of 4-5 people, the students carried out the PBL activities following the eight steps of Fogarty's (1997) problem-based learning model. Students could use graphic organizers such as mind-maps or concepts maps to which they had been exposed in previous science lessons to solve real life problems. At the end of the learning sessions, the groups shared their results with the class, while other groups made their comments. From the input given by their peers, the groups made improvements to their solutions. Then the teacher concluded the day's lesson with the whole class.

CPS

The students taught in the CPS group learned Physical Sciences in a large group. The teacher taught the class using a textbook. Students listened to the teacher's explanation about the topics and made relevant notes in their workbooks. Students then solved the problems provided in the textbook using their own exercise books. The given problems and answers to the problem did not necessarily relate to real life situations. The students solved the problems individually and used a textbook or workbook as their main reference. The students then submitted their work to the teachers who marked them and returned the students' work.

At the end of the intervention, a post-test measure of motivation was conducted. Students from both the treatment and controlled groups answered the questionnaire individually and mean scores were calculated as an indicator of the change of their motivation towards science learning.

In addition, a critical thinking test developed by researchers (Mapeala & Siew, 2015) was administered to the students earlier and later after the intervention.

The Training of Teachers

Teachers who participated in this research were given a two-hour special training and coaching on the implementation of TM-PBL, PBL, and CPS methods prior to the start of the research. Teachers were provided with the complete TM-PBL module which contained information about the concept of PBL, thinking maps, and suggested outcomes for each activity. Teachers were also taught how to facilitate the group activities in PBL. The researchers monitored the teachers from time to time through social visits to ensure the consistency and reliability of the implementation. The selection of teachers was based on their willingness and readiness to be involved in the research and who had more than a decade's experience of teaching science. They were then assigned to teach the three classes using the three methods: TM-PBL, PBL, and CPS.

Data Analysis

Preliminary Analysis

Preliminary analysis was conducted to check whether the prerequisite assumptions of MANOVA / MANCOVA were met. Thus, the assumptions centered to MANOVA / MANCOVA in the statistical analysis were examined for: (a) multivariate normal distribution, (b) equality of group population covariance matrices, (c) linear relationship between covariates and dependent variables, (d) absent of multicollinearity, and (e) homogeneity of dependent variable variance.

Pre-experimental Research

The purpose of the pre-experimental research was to test the assumption that the respondents across the three teaching groups were equivalent in their prior motivational factors: pre-SE, pre-ALS, pre-SLV, pre-PG, pre-AG and pre-LES. To examine if there were any significant statistical differences among the students' mean scores on their prior motivation across the three groups, the one-way multivariate analysis of variance (MANOVA) was conducted. If the overall multivariate test (MANOVA) was not significant, univariate F test (ANOVA) was examined to further identify the presence or non-presence of significant statistical differences between students across the three teaching groups in each of the students' prior motivational factors.

A multivariate analysis of covariance (MANCOVA) was conducted (with prior motivation as the covariates) to investigate the main effects of the three different teaching methods on students' post-SE, post-ALS, post-SLV post-PG, post-AG and post-LES, while controlling the three covariates. By employing the MANCOVA, the extraneous differences among groups can be controlled after removal of the effects of covariates from the dependent variables (Hair, *et al.,* 2010).

If the overall multivariate test (MANCOVA) was significant, univariate F test (ANCOVA) was carried out on post-motivation mean scores with pre-motivation mean scores as covariates to further examine if there was a significant statistical main effect of teaching groups on each of post-SE, post-ALS, post-SLV post-PG, post-AG and post-LES.

The assumptions that were used for the MANCOVA / MANOVA and inferential statistics analyses were tested using SPSS for Windows (Version 22). Alpha value was set at 0.05 level of significance. The Wilk's Lambda was used to evaluate the multivariate differences in this research as it is mostly applied in multivariate tests to examine differences between the means of identified groups of subjects on a combination of dependent variables (Everitt & Dunn, 1991). The effect size index (f) was calculated from eta square (η^2). According to Cohen's rough characterization (Cohen 1988, p. 284-288), $0.2 \leq f \leq 0.4$ is deemed as a small size effect, $0.4 < f \leq 0.7$, a medium size effect, and $0.7 < f \leq 1.0$, or $1 \leq f$ as the large size effect (for interpreting η^2, $0.010 \leq \eta^2 \leq 0.039$= small, $0.039 < \eta^2 \leq 0.11$= medium, and $0.11 < \eta^2 \leq 0.20$ = large effect size).

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Results of Research

The descriptive statistics of students' pre-test and post-test measures of motivation towards science learning in self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation are summarized in Table 1.

Table 1. 7 Students' motivation towards science learning between pre- and post-teaching.

Motivational factor	Teaching Group	N	Pre-test		Post-test	
			Mean	SD	Mean	SD
Self-efficacy	TM-PBL	90	4.091	.408	4.480	.264
	PBL	90	4.198	.342	4.233	.288
	CPS	90	4.113	.408	4.234	.260
	Total	270	4.127	.388	4.316	.294
Active Learning Strategies	TM-PBL	90	4.017	.427	4.293	.226
	PBL	90	3.923	.332	4.055	.227
	CPS	90	3.883	.353	3.986	.235
	Total	270	3.941	.376	4.112	.264
Science Learning Value	TM-PBL	90	4.089	.508	4.356	.328
	PBL	90	4.122	.448	4.284	.286
	CPS	90	4.133	.398	4.189	.233
	Total	270	4.115	.453	4.276	.292
Performance Goal	TM-PBL	90	3.783	.641	4.239	.382
	PBL	90	3.894	.613	4.222	.364
	CPS	90	3.977	.606	4.119	.417
	Total	270	3.885	.623	4.194	.390
Achievement Goal	TM-PBL	90	4.282	.410	4.580	.297
	PBL	90	4.131	.461	4.271	.389
	CPS	90	4.158	.450	4.182	.430
	Total	270	4.190	.444	4.344	.412
Learning Environment Stimulation	TM-PBL	90	3.942	.427	4.453	.323
	PBL	90	4.001	.402	4.313	.409
	CPS	90	4.003	.364	4.220	.362
	Total	270	3.983	.398	4.329	.377

The Pre-experimental Research Results

The results of MANOVA indicated that there were significant statistical differences among the students' mean scores on their prior motivation across the three groups ($p=.003$). Further univariate F test (ANOVA) indicated that there were significant statistical differences between students' pre-test measures of motivation across the three teaching groups in the self-efficacy, active learning strategies, and achievement goal (Table 2). According to Pallant (2002), the use of covariate as a baseline measurement taken at the beginning of a study helps improve the research design by removing some of the variation in the data. Accordingly, this research corrected the differences between groups at baseline by employing the pre-test measures of motivation as covariates. An Analysis of Covariates (ANCOVA) and Multivariate Analysis of Covariance (MANCOVA) were then performed in the data analysis. Portney and Watkins (2002), and Salinsky, Storzbach, Dodrill, & Binder (2001) indicated that MANCOVA is able to control the potential influence of individual differences resulting in differences observed amongst treatment conditions to reflect treatment effects and not the variability between the subjects.

Table 2. Summary of Multivariate Analysis of Variance (MANOVA) results and followed-up ANOVA results on pre-motivation mean scores.

Dependent variables	Multivariate, F	Univariate, F
Group effect	**Wilks' Lambda** F(12,524) = 2.535, p=.003	
Self-efficacy		F(2,267) = 3.255, p=.040
Active learning Strategies		F(2,267) = 3.629, p=.028
Science Learning Value		F(2,267) = 0.234, p=.792
Performance Goal		F(2,267) = 2.223, p=.110
Achievement Goal		F(2,267) = 3.013, p=.051
Learning Environment Stimulation		F(2,267) = 0.684, p=.506

Determination of Covariates

The six covariates (pre-SE, pre-ALS, pre-SLV, pre-PG, pre-AG and pre-LES) were predetermined as potential confounding factors prior to conducting the MANCOVA. In order to ensure the variables in the covariate were set to high correlated ones with the dependent variables (Cohen & Cohen, 1983), these potential covariates were correlated with the dependent variables. Pre-SE, pre-ALS, pre-SLV, pre-PG, pre-AG and pre-LES had significant correlations with at least one dependent variable (Table 3). Therefore, they remained in the covariate set for the inferential statistics.

Table 3. Correlation coefficients between covariates and dependent variables.

		Covariate					
		Pre SE	**Pre ALS**	**Pre SLV**	**Pre PG**	**Pre AG**	**Pre LES**
Dependent variables	Post SE	.280**	.282**	.139*	.109	.153*	.067
	Post ALS	.420**	.425**	.144*	.046	.202**	.059
	Post SLV	.251**	.259**	.272**	.094	.173**	-.001
	Post PG	.195**	.208**	.107	.293**	.159**	.180**
	Post AG	.178**	.189**	.014	.024	.356**	.140*
	Post LES	.199**	.207**	.059	.006	.172**	.239**

***Correlation is significant at the 0.01 level (2-tailed)*
**Correlation is significant at the 0.05 level (2-tailed)*

Preliminary Analysis

Preliminary analysis indicated adequate conformity to all univariate and multivariate assumptions of MANOVA / MANCOVA for: (a) multivariate normal distribution, (b) equality of group population covariance matrices, (c) linear relationship between covariates and dependent variables, (d) absent of multicollinearity, and (e) homogeneity of dependent variable variance.

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The Experimental Research Results

A MANCOVA analysis indicated significant main effects of teaching methods on students' motivation towards science learning (Wilk's λ =.665, F (12, 512) = 9.659, $p < 0.05$) as shown in Table 4.

Table 4. MANCOVA analysis for group effects.

Wilks' Lambda	F	Hypothesis df	Error df	Sig. of F	Eta Squared η^2	Effect Size, f
.665	9.659	12	512	< .05	.185	0.476

Follow-up ANCOVA showed that there were significant main effects of teaching methods on Self-efficacy [F(2, 261) = 21.193, $p < .05$, $\eta^2 = .140$], Active Learning Strategies [F(2, 261) = 37.372, $p < .05$, $\eta^2 = .223$], Science Learning Value [F (2, 261) = 6.031, $p = .003$, $\eta^2 = .044$], Performance Goal [F(2, 261) = 2.899, $p = .057$, $\eta^2 = .022$], Achievement Goal [F(2, 261) = 21.409, $p < .05$, $h^2 = .141$], and Learning Environment Stimulation [F(2, 261) = 7.346, $p = .001$, $\eta^2 = .053$]. A high relationship between the teaching method and Self-efficacy, Active Learning Strategies and Achievement Goal was obtained, indicating that 14%, 22.3%, and 14.1% of the variance obtained respectively, was accounted by the teaching methods. Nonetheless, a medium to small relationship between the teaching method and Learning Environment Stimulation, Science Learning Value, and Performance Goal was obtained, indicating that 5.3%, 4.4%, and 2.2% of the variance obtained respectively, was accounted by the teaching methods.

Further testing using the Post hoc Pair-wise test revealed that students taught via the TM-PBL teaching method gained significantly higher than their counterparts in the PBL group in Self-efficacy ($R_{SE} < .05$), Active learning strategies ($R_{ALS} < .05$), Achievement Goal ($R_{AG} < .05$) and Learning environment stimulation ($R_{LES} = .029$) (Table 5). However, students taught in the TM-PBL group did not gain significantly higher levels than their counterparts in the PBL group in Science Learning value ($R_{SLV} = .265$,), and Performance Goal ($R_{PG} = .924$). Therefore, the first research hypothesis was mostly supported.

Likewise, students taught via the TM-PBL teaching method gained significantly higher levels than their counterparts in the CPS group in Self-efficacy ($R_{SE} < .05$), Active learning strategies ($R_{ALS} < .05$), Science Learning value ($R_{SE} = .001$), Performance Goal (($R_{SE} = .037$), Achievement Goal ($R_{AG} < .05$) and Learning environment stimulation ($R_{LES} < .05$). Therefore, the second research hypothesis was fully supported.

Furthermore, students taught via the PBL teaching method gained significantly higher levels than their counterparts in the CPS group in Active learning strategies ($R_{ALS} < .05$), Science Learning value ($R_{SLV} = .265$,), and Performance Goal ($R_{PG} = .924$). However, students taught in the PBL group did not gain significantly higher levels than their counterparts in the CPS group in Self-efficacy ($R_{SE} = .895$), Achievement Goal (R_{AG}=.080) and Learning environment stimulation ($R_{AG} = .090$). Therefore, the third research hypothesis was partially supported.

Table 5 shows a large effect size for comparing between the TM-PBL and PBL methods, and between TM-PBL and CPS methods in Self-efficacy (0.894 and 0.938 respectively), Active learning strategies (1.000 and 1.331 respectively) and Achievement Goal (0.892 and 1.077 respectively). Meanwhile, the analysis showed a small to moderate effect size for the comparison between TM-PBL and PBL, and between TM-PBL and CPS in Science Learning value (0.233 and 0.587 respectively), Performance Goal (0.044 and 0.300 respectively), and Learning environment stimulation (0.379 and 0.679 respectively). On the other hand, a small effect size was observed for comparing the PBL and CPS methods in Active learning strategies (0.298), Science Learning value (0.364), Performance Goal (0.263), Achievement Goal (0.217) and Learning environment stimulation (0.240).

Table 5. Summary of post hoc pairwise comparison.

Comparison Group	Mean Difference	Sig.	Effect Size (d)	Interpretation
		Self-efficacy		
TM-PBL vs PBL	.229	< .05	0.894	Large
TM-PBL vs CPS	.234	< .05	0.938	Large
PBL vs CPS	.005	.895	0.000	No effect

Comparison Group	Mean Difference	Sig.	Effect Size (*d*)	Interpretation
		Active Learning Strategies		
TM-PBL vs PBL	.199	< .05	1.000	Large
TM-PBL vs CPS	.274	< .05	1.331	Large
PBL vs CPS	.075	.018	0.298	Small
		Science Learning Value		
TM-PBL vs PBL	.046	.265	0.233	Small
TM-PBL vs CPS	.142	.001	0.587	Medium
PBL vs CPS	.095	.020	0.364	Small
		Performance Goal		
TM-PBL vs PBL	.005	.924	0.044	Small
TM-PBL vs CPS	.119	.037	0.300	Small
PBL vs CPS	.113	.040	0.263	Small
		Achievement Goal		
TM-PBL vs PBL	.255	< .05	0.892	Large
TM-PBL vs CPS	.348	< .05	1.077	Large
PBL vs CPS	.093	.080	0.217	Small
		Learning Environment Stimulation		
TM-PBL vs PBL	.119	.029	0.379	Small
TM-PBL vs CPS	.210	< .05	0.679	Medium
PBL vs CPS	.090	.090	0.240	Small

Discussion

Cumulatively, the research findings above showed that students taught via the TM-PBL teaching method gained significantly higher levels than their counterparts in the PBL group in Self-efficacy, Active learning strategies, Achievement Goal and Learning Environment Stimulation. However, students taught in the TM-PBL group did not gain significantly higher levels than their counterparts in the PBL group in Science Learning value and Performance Goal. Likewise, students taught via the TM-PBL teaching method gained significantly higher levels than their counterparts in the CPS group in all motivational factors.

On the other hand, students taught via the PBL teaching method gained significantly higher levels than their counterparts in the CPS group in Active learning strategies, Science Learning value and Performance Goal. However, students taught in the PBL group did not gain significantly higher levels than their counterparts in the CPS group in Self-efficacy, Achievement Goal and Learning Environment Stimulation.

A large effect size for comparing the TM-PBL and PBL method, and the TM-PBL and CPS method indicates that the TM-PBL method is the most effective teaching method amongst the three in promoting Self-efficacy, Active learning strategies, and Achievement Goal among Fifth graders. A small and medium effect size was observed for comparing the TM-PBL and PBL method, and the TM-PBL and CPS method, respectively in Learning environment stimulation. Overall, students taught via PBL method gained significantly higher than those taught via the CPS method with a small effect size in Active learning strategies, Science Learning value, and Performance Goal, but not in Self-efficacy, Achievement Goal and Learning Environment Stimulation factors.

Self-efficacy. Students' self-efficacy was significantly enhanced after learning in the TM-PBL teaching method compared to their peers learning in the PBL and CPS method. The elements of teaching *about* thinking (TM) and teaching *for* thinking (PBL) were more direct and explicitly infused in the TM-PBL method compared to the PBL and CPS method. Such conditions allowed the TM-PBL group to practice both thinking and problem-solving skills more effectively and at the same time learn about the Physical Science content in groups. When PBL was infused with the utilization of explicit thinking maps as scaffolding tools with guidance from the teacher, an effective learning

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environment for fostering motivation towards science learning was created. Consequently, students believed that they could do well on the science critical thinking test, think for themselves, try to learn physical science content and understand difficult Physical Science content. This is aligned to the research findings in educational psychology that informs educators of the importance of appropriate scaffolding to bring about feelings of self-efficacy (Tan, 2004). As a consequence, students learning with TM-PBL methods were able to gain better levels than their counterparts in the PBL and CPS methods in self-efficacy belief.

Active learning strategies. Students' active learning strategies were significantly boosted after learning in the TM-PBL teaching method compared to their peers who learned in the PBL and CPS method. In the TM-PBL method, students took an active role to understand the newly learned science concepts by associating them with their previous experiences using active learning strategies such as brainstorming in groups using thinking maps. Students were actively engaged in group discussion with peers and teachers in clarifying their understanding. In the group discussions, students had the opportunity to exchange ideas, look for additional insights and information that enables them to acquire a deeper and better understanding of the problem at hand. They tried to figure out reasons a mistake was done amongst group members. Consequently, students perceive the value and meaning of the learning tasks. When students took an active role to understand the newly learned science concepts using a variety of strategies, they were motivated to learn science.

Achievement Goal and Learning environment stimulation. Another finding in this research showed that students taught via TM-PBL method improved achievement goal and learning environment stimulation factors better compared to the PBL and CPS method. Students felt most fulfilled working in the TM-PBL method when they increased their competence and achievement in getting a good score in a test, solving a difficult problem, getting their ideas accepted by teachers and peers, and feeling confident about the science content.

Likewise, students were willing to participate in PBL and TM activities because they perceived that the activities were exciting and challenging. Students felt that teacher used a variety of teaching methods and paid attention to them. As students produced Thinking Maps, interaction between them and their thinking maps occurred. Consequently, the students truly appreciated the group interaction and the challenging nature of the problem. As pointed out by Dev (1997), "A student who is intrinsically motivated . . . is more likely to complete the chosen task and be excited by the challenging nature of an activity" (p. 13).

Science Learning Value and Performance Goal. Students working in the PBL-TM teaching method did not report significant increases in their science learning value and performance goal compared to their peers taught with the PBL method. This research revealed that students working in the PBL-TM method perceived the similar science learning values with the students learning in the PBL teaching method. The PBL method shares a similar unique feature with the TM-PBL method in highlighting the value of science learning. In the TM-PBL and PBL environment, students' prior knowledge was activated while solving provided ill-structured and real-life problems. Students were engaged in deeper learning and insights into real-life problems interim working together in small groups. With the support of peers, students in both classes of teaching methods perceived that they were capable of accomplishing learning tasks. Students discovered the value of science learning when they realized the relevance of science problems with their daily lives. Consequently, students were encouraged to be intrinsically motivated to seek out solutions. In other words, students' motivation in both groups was enhanced through solving real world issues and problems as supported by Cetin-Dindar (2016) who posit that students are more motivated to learn science when they had more opportunities in relating science with real world issues. Students were also engaged in demonstrating skilful thinking in solving problems. When students believed that acquiring problem-solving competency, experiencing the inquiry activity, stimulating their own thinking, and finding the relevance of science with daily life is important socially as well as academically, they would be more motivated to learn science. Unfortunately, thinking maps could not help students learning in the PBL teaching method to perceive more enhanced Science Learning Value in order to get them motivated to learn science.

Similarly, both the PBL-TM and PBL teaching method involved cooperative activities, thus students perceived that their goals in science learning were not inclined to compete with other students in getting a better grade or performance in class, or getting more attention from the teacher. This is supported by Sisovic and Bojovic (1999) who found that cooperative learning could increase students' self-respect and reduce competition anxiety.

In contrast, students taught via the CPS teaching method achieved significantly lower levels than their counterparts taught in the TM-PBL group in all motivational factors. The teachers in the CPS group did not expose their students to real-world problems to stimulate the students' interest and thinking. No specific attention was given to creating a general feeling of cooperation within the learning groups. Thus, there were fewer opportunities for students to share their thoughts and views with others as a supportive atmosphere was lacking for meaningful discussion within the groups. The instruction in the CPS method had no inclusion of constructivist learning and motivation theories for the development of motivation towards science learning. Therefore, the students in the CPS group were unable to gain as much motivation towards science learning in all motivational factors as students working in the TM-PBL group.

Another finding in this research showed that students taught via the PBL teaching method improved the Active learning strategies, Science Learning value, and Performance Goal factors significantly better than their counterparts in the CPS group. In the PBL teaching method, students took a more active role in group discussion with peers in clarifying their understanding while solving an ill-structured and real life problem. They worked together in small groups to go through inquiry activities by connecting their existing knowledge with new experience. In contrast, students in the CPS group tackled the problem individually. Consequently, students perceived more value and meaning of the learning tasks, and were more motivated to learn science compared to their peers taught in the CPS method. When students believed that acquiring problem-solving competency and inquiry skills, stimulating their own thinking, and finding the relevance of science with daily life is important, they would be more motivated to learn science. Mac Iver, Stipek, and Daniels (1991) also indicated that the use of challenging problems and activation of prior knowledge could positively influence perceptions of competence and competence can afterwards influence intrinsic motivation. Similarly, students taught via the PBL teaching method were more inclined to certain behaviours such as competitiveness and getting attention compared to their peers taught in the CPS method.

However, students taught in the PBL group did not achieve significantly higher levels than their counterparts in the CPS group in Self-efficacy, Achievement Goal, and Learning environment stimulation factors. Due to the students' responsibility for solving real-life problems in PBL, this form of learning requires drastic changes in the roles of students. Many studies have shown that students do not adapt easily to change, and that the self-efficacy belief can be both indicators of change during instructional interventions and indicators of initial individual differences (Zimmerman, 2000). The low gains of students' self-efficacy in the PBL group could be due to an inability to adapt to the change during the instructional interventions or initial individual differences in self-efficacy as found in the pre-experimental research results. Furthermore, self-efficacy beliefs are hypothesized to be mediators of behavioral change (Zimmerman, 2002; Sungur & Tekkaya, 2006) and developed from four sources: direct experiences, vicarious experiences from observing peers, persuasion by others, and personal physiological reactions (Bandura, 1998). These four sources could not be sufficiently developed within nine weeks of intervention under the study. Consequently, students perceived the same ability with their counterparts in the CPS group to answer the science critical thinking test, think for themselves, learn physical science content, and understand difficult Physical Science content.

Raidal and Volet (2009) state that beginner students were found to prefer individualistic learning over group work, and teacher-directed learning over self-directed studies. They perceived group work and self-directed learning as complicated and overcharging study conditions (Raidal & Volet, 2009; Hendry, Lyon, Prosser, & Sze, 2006). In this study, a proportion of students were likely unable to self-regulate their learning due to a lack of experience working in PBL. As a consequence, students working in the PBL group felt the same level of satisfaction about their competence and achievement with their peers taught with the CPS method in getting a good score in a test, solving a difficult science problem, getting their ideas accepted by teachers and peers, and feeling confident about the science content. In addition, they perceived the learning environment created in the PBL method did not significantly increase their willingness to participate in the activities. The students perceived that they had the same level of involvement in discussions and received the same teachers' teaching methods and attention as their peers in the CPS group. Dochy, Segers, Van den Bossche, and Struyven (2005) also indicated that group difficulties and slackers could be some aspects hindering the PBL process.

The outcome of this research findings suggests for a more detailed focus on the TM-PBL method in physical science lessons to help Fifth Graders gain better motivation towards science learning in Self-efficacy, Active learning strategies, Achievement Goal and Learning environment stimulation.

Conclusions

This research contributes valuable information to the literature in the field of science education by demonstrating empirical evidences that students' motivation towards science learning can be fostered through a TM-PBL teaching method in primary Physical Science lessons. Overall, Fifth Graders learning with TM-PBL methods were

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able to use TM as a strategy to foster their motivation more effectively in all motivational factors compared to CPS methods. In other words, the more explicit teaching is *about* thinking and *for* thinking, the more substantial the impact it has on students' motivation towards science learning. Creating a learning environment that employs the PBL method is effective to foster the Science Learning value and Performance Goal factors. However, PBL is not a sufficient condition to effectively promote students' motivation towards science learning in Self-efficacy, Achievement Goal and Learning environment stimulation. Thinking maps that teach about thinking are necessary to help PBL gain maximum effectiveness in promoting those three motivational factors. This research exhibits that emphasis on teaching about thinking in the teaching and learning of primary Physical Science lessons using specific thinking maps like Double Bubble Maps, Flow Maps, and Multi-Flow Maps are able to increase PBL's effects to enhance students' motivation towards learning.

The results suggest that science educators should adopt a similar TM-PBL teaching method to increase the motivation towards science learning among primary school students. Interim, this research also supports new research examining the potential effects of an infusion approach using different thinking maps and teaching methods in fostering subject-specific motivation towards learning among primary school students.

However, this research did not demonstrate significant difference effects of TM-PBL on motivational factors of the SMTSL scale in Science Learning Value and Performance Goal compared to the PBL method. Thus, two interventions would help to further clarify the remaining gaps of TM-PBL in fostering students' motivation towards science learning: 1) a longer intervention period with extra learning activities and real-life problems compared to the current research, and 2) a mixed research method with a larger sample size. Further comparison between rural and urban schools would shed light on the extent to which locality influences students' motivation towards science learning.

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