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THE EFFECT OF COOPERATIVE LEARNING WITH DSLM ON CONCEPTUAL UNDERSTANDING AND SCIENTIFIC REASONING AMONG FORM FOUR PHYSICS STUDENTS WITH DIFFERENT MOTIVATION LEVELS

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Abstract. The purpose of this study was to investigate the effect of Cooperative Learning with a Dual Situated Learning Model (CLDSLM) and a Dual Situated Learning Model (DSLM) on (a) conceptual understanding (CU) and (b) scientific reasoning (SR) among Form Four students. The study further investigated the effect of the CLDSLM and DSLM methods on performance in conceptual understanding and scientific reasoning among students with different motivation levels. A quasi-experimental method with the 3 x 2 Factorial Design was applied in the study. The sample consisted of 240 students in six (form four) classes selected from three different schools, i.e. two classes from each school, with students randomly selected and assigned to the treatment groups. The results showed that students in the CLDSLM group outperformed their counterparts in the DSLM group—who, in turn, significantly outperformed other students in the traditional instructional method (T) group in scientific reasoning and conceptual understanding. Also, high-motivation (HM) students in the CLDSLM group significantly outperformed their counterparts in the T groups in conceptual understanding and scientific reasoning. Furthermore, HM students in the CLDSLM group significantly outperformed their counterparts in the DSLM group in scientific reasoning but did not significantly outperform their counterparts on conceptual understanding. Also, the DSLM instructional method has significant positive effects on highly motivated students' (a) conceptual understanding and (b) scientific reasoning. The results also showed that LM students in the CLDSLM group significantly outperformed their counterparts in the DSLM group and (T) method group in scientific reasoning and conceptual understanding. However, the low-motivation students taught via the DSLM instructional method significantly performed higher than the low-motivation students taught via the T method in scientific reasoning. Nevertheless, they did not perform significantly higher in conceptual understanding. Finally, the results showed that there were no significant interaction effects between student motivational levels and instructional methods for the scientific reasoning and conceptual understanding scores.

Keywords: conceptual understanding, scientific reasoning, cooperative learning with Dual Situated Learning Model

Introduction

The aim of the study is to investigate the teaching of physics according to the constructivist paradigm. The teaching model chosen is based on well known theoretical frameworks from the science education and cognitive psychology theories of Piaget, Posner and Vygotsky. This study focuses on investigating the effects of using cooperative learning and a conceptual change model, the Dual Situated Learning Model (DSLM), on form four students' physics conceptual understanding and scientific reasoning. The study also investigates the relationship between student motivation and the process of conceptual understanding. Five general motivational constructs—mastery goals, epistemological beliefs, values, self-efficacy and test anxiety—are suggested as potential mediators of the process of conceptual understanding and scientific reasoning.

Many studies have demonstrated that students of all ages suffer from an incomplete or inaccurate understanding of many scientific phenomena (Smith et al., 1985; Westbrook & Marek, 1991). These misconceptions have been shown to be pervasive, stable, and often resistant to change through classroom instruction (Osborne & Wittrock, 1983). Since the last decade, science educators have concentrated on studying misconceptions held by students. Students' ideas in science prior to formal instruction have become a major concern among researchers in science. Numerous studies on a large number of related topics have been published (Carmichael et al., 1990; Pfundt & Duit, 1991). The substantial evidence thus accumulated has indicated that students have already acquired considerable knowledge and ideas about the natural and technological world before they have enjoyed any formal instruction. More importantly, some of these intuitive conceptions are found to differ from the accepted scientific views and have been variously labeled in the science education literature as misconceptions (e.g., Helm, 1980), preconceptions (e.g., Novak, 1977), alternative conceptions (Driver & Easley, 1978) or children's science (Gilbert et al., 1982). Furthermore, these intuitive conceptions have been found to be extremely robust to change and, often, to remain intact in children and adults alike even after completion of years of formal science instructions.

Since the middle of the 1980s the investigation of students' conception at meta-levels, namely conceptions of the nature of science and views of learning (i.e., meta-cognitive conceptions) also have been given considerable attention. Research shows that students' conceptions here are also rather limited and naive. Thus, the problem of how to bring about conceptual change in learners becomes a major challenge for science educators. However, much of this research only concentrates on the cognitive construct. The issue of motivation has been either ignored or merely foreshadowed in conceptual change research. Pintrich and colleagues introduced a broader view of the learner, one in which cognitive and motivational constructs operate in interaction, to the study of knowledge restructuring. Pintrich et al. (1993a) explained how a host of specific motivational constructs could affect the process of knowledge change. The constructs addressed included mastery goals, epistemological beliefs, personal interests, values, self-efficacy, attitudes and control beliefs. This laid the groundwork for the role of these and other motivational constructs to be explored in future research.

Motivational constructs often present a doubled-edged sword in that the valence of the constructs can have a positive or negative effect on the learning outcome. This is especially important in conceptual change research to determine whether a construct acts as a facilitator or an inhibitor of change—that is, whether the impact encourages adopting a new idea or resisting it. While various theories have recognized the importance of conceptual change, little attention has been paid to the empirical study of the effect of motivational factors and cooperative learning with instructional models such as DSLM on conceptual understanding and scientific reasoning skill among physics students.

Literature review

Vygotsky (1978) believes that social interaction among students and their peers enables them to extend their knowledge. He believes that there is a hypothetical region where learning and development best take place. He identifies this region as the zone of proximal development (McLoughlin & Oliver, 1988). This zone is defined as the distance between what an individual can accomplish during independent problem-solving and what can be accomplished with the help of an adult or a more capable member of a group. With cooperation, direction, or help, the individual is better able to solve more difficult tasks than he or she could independently be.

The belief that peer interaction may promote learning has been applied systematically under the rubric of "cooperative learning". Cooperative learning is an instructional technique in which students work together in structured small groups in order to accomplish shared goals (Johnson & Johnson, 1989). Research indicates that cooperative learning groups seem to help all students because the best students get to "impart" their knowledge to others and the weaker students receive peer coaching (Heller et al., 1992). Furthermore, Vygotsky (1978) suggests that an active student and an active social environment cooperate to produce developmental change. The student actively explores and tries alternatives with the assistance of a more skilled partner, as in an instructor or a more capable peer.

Recent studies have argued that conceptual change in learning is often an incremental process (Duschl & Gitmoer, 1991) that may be driven by a range of hot, irrational, social, and motivational forces (Pintrich et al., 1993). According to the DSLM proposed by She (2001), students are motivated to learn science out of curiosity aroused by events that create dissonance and present a new schema for them. Therefore, the purpose of this research is to examine cooperative learning with DSLM for conceptual change and ascertain the relationship, if any, between motivational factors such as mediators and conceptual change.

The Dual Situated Learning Model (DSLM) was developed by She (2001, 2002), Institute of Education, National Chiao-Tung University Taiwan for Conceptual Change. This model is built upon well known theoretical frameworks from science education and cognitive psychology theories (Piaget, 1974; Posner et al., 1982; Steinberg & Frensch 1996; Steinberg & Clement, 1997; Rea Ramirez & Clement, 1998). This approach emphasizes students' ontological view of a concept and the attributes of that concept, with these serving as the bases for the development of dual situated learning events. Each dual situated learning event has two functions: creating dissonance with students' pre-existing knowledge and providing a new mental set with which to construct more scientific concepts. The new mental set should, as Posner et al. (1982) suggest, enable students to see the new concept as intelligible, plausible, and fruitful. The dual situated learning events can be any type of instructional activity, such as analogy, modeling, discrepant events or inquiry-based activities.

The DSLM is composed of six major stages as follows: Stage 1 - examining the attributes of the science concept. This stage provides information about which essential mental sets are needed to construct a scientific view of the concept. Stage 2 - probing students' misconceptions of the science concept, which requires probing students' beliefs concerning the science concept. Stage 3 - analyzing which mental sets students lack. This would reveal which mental sets students lack specifically for the construction of a more scientific view of the concept. Stage 4 - designing dual-situated learning events. The design of a dual-situated learning event is according to the Stage 3 results, indicating which mental sets students' lack. If two mental sets are needed to help students construct a more scientific view of the concept, it might be necessary to design at least two dual situated learning events. Stage 5 - instructing with dual-situated learning events. This emphasis gives students an opportunity to make predictions, provide explanations, confront dissonance, and construct a more scientific view of the concept. Stage 6 - instructing with challenging situated learning event. This provides an opportunity for students to apply the mental sets they have acquired to a new situation to ensure that successful conceptual change has occurred.

Studies on buoyancy and air pressure, (She, 2002) and on thermal expansion (She, 2003) with Taiwanese students found evidence of conceptual change introduced by the DSLM through classroom instruction. During the instruction with DSLM, students were not allowed to discuss the ideas with each other, and their teachers were not allowed to provide any explanation or correct the students. The results demonstrated that without any intervention from the teacher, students could still learn by themselves from a series of dual situated learning events. Solomon (1987) proposed that social factors have a significant influence on classroom learning and knowledge construction. In addition, progress in reforming children's intuitive conceptions appears to be most successful when the social milieu of the classroom becomes a platform for constructing the desired science concepts (Hennessey, 1993). It is plausible that putting this model together with cooperative learning into actual classroom teaching and taking the social factors suggested by Solomon (1987) into consideration would result in the more successful promotion of conceptual understanding and scientific reasoning among students.

Purpose of the study

In line with the "Revised Curriculum" of the Integrated Curriculum for Secondary Schools (KBSM), this study was undertaken to investigate the extent to which cooperative learning with a Dual Situated Learning Model (CLDSLM) could help to increase conceptual understanding and scientific reasoning for physics. It also examined the moderating effects of motivational level on students' physics conceptual understanding and scientific reasoning. Thus, the purpose of this study was to ascertain the extent to which the cooperative learning with Dual Situated Learning Model (CLDSLM) methods could play a role in improving Malaysian Form Four students' conceptual understanding performance and, scientific reasoning skills. Particularly, the study is conducted to investigate if there were any significant differences in conceptual understanding and scientific reasoning levels between students taught via cooperative learning with the Dual Situated Learning Model (CLDSLM), students taught via the Dual Situated Learning Model learning alone as the instructional method (DSLM), and students taught via the traditional instructional method (T).

The study also examines the effects of the instructional methods on highly motivated and low-Motivation students' conceptual understanding performance, and scientific reasoning. This study focuses on the comparison between three different forms of learning—i.e., cooperative learning with DSLM instructional methods (CLDSLM), DSLM without cooperative learning and the traditional group method (T). All instructional strategies use heterogeneous-ability grouping but differing in participant structure, where the experimental groups use both cooperative learning with the Dual Situated Learning Model and the Dual Situated Learning Model without cooperative learning, whereas the control group and the traditional group (T) will use neither. Furthermore, the study investigates the effects of this instructional strategy on highly motivated students and low-motivation students with regard to scientific reasoning and conceptual understanding. The interactions between the instructional methods and students' scientific reasoning and conceptual understanding are also investigated.

Thus, the objectives of the study are: (1) to investigate the effect of using cooperative learning with DSLM in science teaching on students' physics (a) conceptual understanding (CU) and (b) scientific reasoning (SR); (2) to study the interaction effect of the instructional method and motivation level on physics (a) conceptual understanding (CU) and (b) scientific reasoning (SR).

Research questions

This study aims to investigate the effects of cooperative learning with DSLM and the moderating effects of motivation level on students' physics conceptual understanding and scientific reasoning. The research questions are as follows: (i) will students taught via the Cooperative Learning with DSLM (CLDSLM) instructional method perform higher than students taught via the DSLM instructional method, and will the latter in turn perform higher than students taught via T instructional method in physics (a) conceptual understanding (CU) and (b) scientific reasoning (SR); (ii) are there interactional effects between the instructional methods and the motivational levels (highly motivated and low-motivation) in physics (a) conceptual understanding (CU), (b) scientific reasoning (SR).

Hypotheses

Based on the research questions, the following hypotheses were formulated: $H_{01:}$ There is no significant difference in the mean scores for conceptual understanding performance (CU) and scientific reasoning (SR) performance between students taught via the CLDSLM instructional method, students taught via the DSLM instructional method and students taught via the T instructional method. (Xa=Xb=Xt); $H_{02:}$ There is no interaction effect between the instructional method and the students' motivation levels (highly motivated and low-motivation) for physics conceptual understanding (CU) performance and scientific reasoning (SR) performance.

Population and sample

The population of this study was comprised of Form Four students studying at a secondary school in the East Coast of Malaysia. The student groups were comprised of an equal proportion of boys and girls from various socio-economic backgrounds; the students lived in hostels and their own homes. In order to implement this study in a naturalistic school setting, existing classes was used because this was a quasi-experimental design study. The sample consisted of 240 students in six (Form Four) classes selected from three different schools—i.e., two classes from each school. Students in Form Four physics classes were selected in an attempt to obtain a greater number of students with formal reasoning.

The two classes were randomly selected from each school. The size of the classes was fairly similar. Three teachers were selected for the study; they were of equal experience, having been teaching the subject for more than five years. Each of them was assigned to two classes. The experimental groups for CLDSLM consisted of 2 classes (80 students) taught by one teacher, and the DSLM group consisted of 2 classes (79 students) taught by another teacher, while the traditional group also consisted of 2 classes (80 students). The sample size per group meets the statistical power criterion of 0.8 with an alpha level of 0.05 for a moderate effect size (0.5) (Hair et al., 1998). The teachers who taught the experimental groups and control group were exposed to two weeks of training on instructional methods.

A pre-test was administered to students in each school one week before instruction commenced. From the pre-test scores, those schools that had reported means scores that were not significantly different on the reasoning test were chosen; then, the students in those schools were randomly assigned to the CLDSLM, DSLM and T groups. The scores obtained from the motivational test were used to divide the samples into the groups Highly Motivated (Y1) and Low-Motivation (Y2), and the GALT and pre-CU on topic Heat test were used as for covariate measures.

Experimental conditions

The three schools were each randomly assigned to one of the following conditions: CLDSLM: Students were taught physics via the Jigsaw Cooperative Learning with Dual Situated Learning Model method (n = 80). DSLM: Students were taught physics via the Dual Situated Learning Model with no Cooperative Learning (n = 79). T (control group): Students were taught physics via the present classroom practice (traditional method)—that is, without the Dual Situated Learning Model or Cooperative Learning methods (n = 81) (see Table 1).

Table 1. Mechanisms for the three groups

Group 1 (CLDSLM) n = 80	Group 2 (DSLM) n = 79	Group 3 (T) n = 81
Jigsaw Cooperative Learning with Dual Situated Learning Model (CLDSLM)	Dual Situated Learning Model with help from teachers. No Cooperative Learning (DSLM)	Neither Cooperative Learning nor Dual Situated Learning Model
Cooperative Learning with DSLM students worked, discussed, and interacted in groups and used DSLM	Dual Situated Learning Model students worked on the task with help from teachers during Learning Events	Without Cooperative Learning or DSLM
Used Jigsaw cooperative learning when instructing with DSLM events and completing the worksheet on learning event Used Jigsaw cooperative when presenting or during learning events	Without cooperative learning while instructing DSLM learning events and completing the tasks for learning events, but help from teachers available. Without cooperative learning while presenting Learning Events	Without Cooperative learning and Without DSLM

The three groups were different from one another in terms of the instructional method and materials used. The first experimental group, the CLDSLM group, was asked to work in assigned jigsaw cooperative learning groups at two different motivational levels; the students discussed a task with one another and interacted, completing the task using the DSLM instructional method. The second experimental group only made use of the DSLM and help from teachers during learning events without any use of cooperative group work where any discussion between groups would be encouraged. The normal classroom sitting arrangement and interaction between members of the class was restricted. The T group was the control group in this study. The samples in the T group receive systematic intervention and interaction with the experimenter as the one being implemented in the CLDSLM and DSLM groups. In other words, this group experienced the same reactive effects of the learning material, but without the cooperative learning or the DSLM instructional methods.

Research design

This quasi-experimental study was designed to investigate the effects of cooperative learning with a Dual Situated Learning Model and of a Dual Situated Learning Model without the cooperative learning methods on physics conceptual understanding and scientific reasoning skill. The study employed a 3x2 Factorial Design. The study also employed a quasi-experimental pre-test, post-test/control group design (Tuckman, 1999). The study was designed to investigate the effects of the independent variable on the dependent variables at each of the two levels of the moderator variable. The purpose of using a factorial design was to allow the researcher to determine whether the effects of instructional methods were generalizable across all levels of motivation or whether the effects were specific only to a particular level (Gay & Airasian, 2003). The research design is illustrated in Table 2.

Table 2. Research design

Moderator Variable (Motivation)	**Independent Variable (Instructional Method)**		
	CLDSLM	**DSLM**	**T**
High-Motivated (Y1)	1	2	3
Low- Motivated (Y2)	4	5	6

O_1 X1 Y1 O_2 cell (1)
O_3 X2 Y1 O_4 cell (2)
O_5 X0 Y1 O_6 cell (3)

……

O_7 X1 Y2 O_8 cell (4)
O_9 X2 Y2 O_{10} cell (5)
O_{11} X0 Y2 O_{12} cell (6)

X1: CLDSLM
X2: DSLM
X0: T
Moderator Variable
Y1: Highly motivated
Y2: Low-motivation

$O_1 = O_3 = O_5 = O_7 = O_9 = O_{11} =$ Pre-test.

$O_2 = O_4 = O_6 = O_8 = O_{10} = O_{12} =$ Post-test.

The independent variable is this study was the instructional method with three categories: 1) Cooperative learning with the Dual Situated Learning Model (CLDSLM); 2) Dual Situated Learning Model (DSLM); 3) The traditional instructional method (T).

The moderator variable was the motivational level with two categories: 1) Highly Motivated (HM); 2) Low-Motivation (LM).

The dependent variables were: 1) Conceptual Understanding (CU); 2) Scientific Reasoning (SR).

The design of the present study compared three instructional methods. Two of them were the experimental group—i.e., (a) cooperative learning with the DSLM instructional method and (b) DSLM with no cooperative learning—and the control group had (c) the T traditional instructional method with neither cooperative learning nor DSLM. Slavin (1996) recommended the use of such a research design because it enables researchers to hold constant all factors other than the ones being studied. Additionally, the factorial design allowed the researcher to investigate the effects of three different instructional methods and motivational levels on a set of dependent variables and to ascertain whether the effects of instructional method vary depending on the level of motivation.

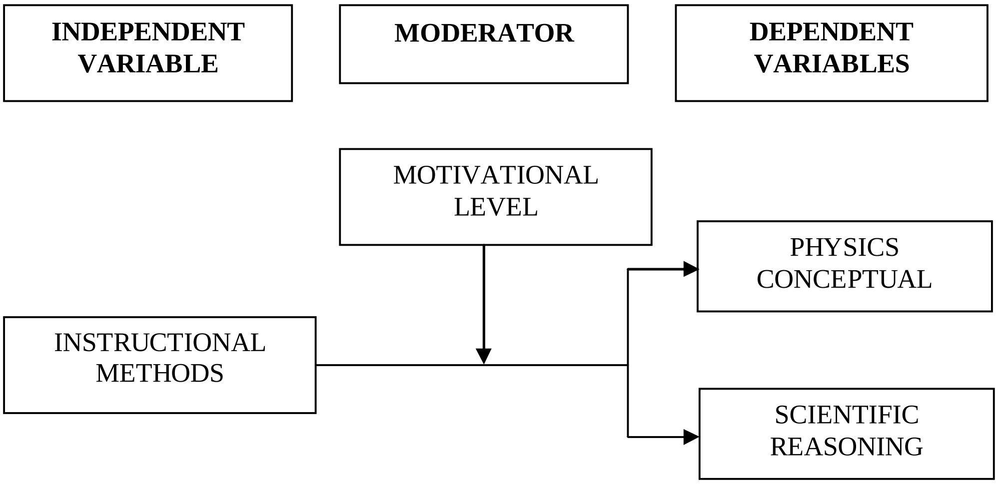


Fig. 1. Design of the study

Research variables

The independent variable for the study was the instructional method, with three categories, namely (a) cooperative learning with the dual situated learning model (CLDSLM) (b) the dual situated learning model (DSLM); and (c) traditional group work (T). The dependent variables in this study were the learners' scientific reasoning skill and conceptual understanding. Scientific reasoning skill is the quality of thought a student was capable of producing using hypothesis and deduction in his or her reasoning. Reasoning skill was measured using Lawson's revised Classroom Test of Scientific Reasoning Skills, the CTSR (Lawsons, 1978) and Roadrangka's Group Assessment of Logical Thinking, GALT (Roadrangka et al., .1983). Roadrangka's Group Assessment of Logical Thinking was used as a pre-test and Lawson's Classroom Test of Reasoning Skill as a post-test with both the treatment and control groups.

The second dependent variable—i.e., conceptual understanding—is the degree to which what a student understands regarding a concept at a particular level corresponds with the scientifically accepted explanation of the concept. Conceptual understanding was measured using the Topic Performance Test (TPT), which has 12 items covering the task given in the context of the topic taught. This test was comprised of both objective and subjective questions. The TPT test was administered as a pre-test and post-test to each CLDSLM, DSLM and T group. Scientific reasoning skill was measured using Roadrangka's Group Assessment of Logical Thinking, GALT. To account for possible pre-existing differences in overall reasoning skill between the treatment groups, the test scores for GALT (pre-SR) and the TPT (pre-CU) were used as covariate measures.

The moderator variable was the learners' motivational level, which was designated as either Low-Motivation (LM) or Highly Motivated (HM). The Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich et al. (1993b) and translated into Bahasa Melayu by Awang-Hashim et al. (2001) was distributed before exposure to the instructional method. This instrument was used to assess the five dimensions of students' motivation with regard to learning physics. The means and standard deviations of the pre-instruction MSLQ scores for the experimental class (N=80) and control class (N=81) were analyzed.

Result

This part presents the results of the study from the data analyses of the pre-experimental study and the experimental study. The analyses were carried out using various statistical techniques, such as multivariate analysis of variance (MANOVA), univariate analysis of variance (ANOVA) and two-way multivariate analysis of covariance (MANCOVA); the two-way analysis of covariance (ANCOVA) per procedure described by Tabachnick & Fidel (2001) and Steven (1986); and post-hoc pairwise comparison using /Imatrix command analysis. A two-way multivariate analysis of covariance (MANCOVA) was conducted to analyze the effects of the instructional method on the two dependent variables and the interaction between the instructional method and the motivation level effects on the two dependent variables.

The statistical differences between the three groups were determined and analyzed according to each of the two dependent variables. The research hypotheses were tested using the results from the two-way multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). The data were compiled and analyzed using Statistical Package for the Social Science (SPSS) for Windows computer software (version 11.5). The results of the analysis were used to answer Research Questions 1-4.

First, the results of the pre-experimental study in response to group’s equivalence are reported. Hypotheses regarding the effects of the instructional methods on students’ conceptual understanding (CU) of heat and scientific reasoning (SR) are tested and their findings presented. Then, the findings regarding the hypotheses about the effects of the instructional methods on Highly Motivated (HM) and Low-Motivation (LM) students’ conceptual understanding (CU) and scientific reasoning (SR) are tested and presented. Each hypothesis tested is followed by a summary of the testing of that hypothesis. Finally, the summary of findings corresponding to the research questions is presented.

The pre-experimental study results

The aim of the pre-experimental study was to test the assumption that the samples across the three groups were equivalent in their conceptual understanding (CU) of heat and scientific reasoning. To fulfill this purpose, a pre-test that measures conceptual understanding of heat and scientific reasoning was conducted before the beginning of the study. Because there were two dependent variables, conceptual understanding of heat and pre-scientific reasoning, as well as an independent variable with three instructional groups and a moderator variable with two levels (LM and HM), two-way Multivariate analysis of variance (or two-way MANOVA) were conducted. To examine if there were significant statistical differences amongst the LM and HM students' mean scores on pre-SR and pre-CU across the three groups, two-way multivariate analysis of variance MANOVA with the splitting file technique (compare group) was conducted.

In addition, the pre-test for scientific reasoning (GALT) and conceptual understanding of heat (pre-TPT) were examined by running a reliability test to determine Cronbach alpha reliability values. The Cronbach alpha reliability coefficients of 0.62305 and 0.8214 were obtained in GALT and pre-TPT, respectively, showing that the two instruments used for this study were satisfactorily reliable.

Statistical data analysis

Table 3 summarizes the descriptive statistics for the dependent variables (pre-CU and pre-SR) by groups. The scores for Highly Motivated students' pre-CU across the three groups had relatively similar means: 10.1750, 10.7368, and 10.0476 for CLDSLM, DSLM, and T, respectively. The scores for Highly Motivated students' pre-SR also had relatively similar means: 6.5000, 6.9474, and 6.9762 for CLDSLM, DSLM, and T respectively. For

Low-Motivation students, the scores of the three groups for pre-CU were very close, (7.5500, 8.1220, and 8.2564 for CLDSLM, DSLM and T, respectively). The scores of the three groups for pre-SR were very close, (2.2750, 1.9756, and 2.4872 for CLDSLM, DSLM, and T, respectively).

Table 3. Mean and standard deviation for each dependent variable (pre-CU and pre-SR), by groups)

Group	Dependent variables Motivation High (HM) Low (LM)		Pre-CU	Pre-SR
CLDSLM	HM (n=40)	Mean	10.1750	6.5000
		SD	1.7525	.5991
	LM (n=40)	Mean	7.5500	2.2750
		SD	1.0857	1.5684
DSLM	HM (n=38)	Mean	10.7368	6.9474
		SD	2.0754	1.1377
	LM (n=41)	Mean	8.1220	1.9756
		SD	1.1289	1.4639
T	HM (n=42)	Mean	10.0476	6.9762
		SD	1.5134	1.8144
	LM (n=39)	Mean	8.2564	2.4872
		SD	1.5706	1.4346

Note. Total score for pre-CU = 22, and total score for pre-SR = 22

To examine if there were significant statistical differences between the Highly Motivated students on pre-CU and pre-SR across the three groups and if there were significant statistical differences between the Low-Motivation students on pre-CU and pre-SR across the three groups, two-way multivariate analysis of variance (MANOVA) was conducted.

Table 4 presents the results of the two-way multivariate analysis of variance, showing overall differences between highly motivated students and low-motivation students across the three groups for pre-CU and pre-SR. In the evaluation of the multivariate (MANOVA) differences, Pillai's Trace criterion was considered to have acceptable power and to be the most robust statistic against violations of assumptions (Coakes & Steed, 2001).

The MANOVA results comparing highly motivated students against highly motivated students and low-motivation students against low-motivation students across the three groups were statistically insignificant (F = 1.773, p = .135), (F = 2.255, p = .064). Further, the results of the univariate ANOVA tests (Table 4.2) indicated that there were no significant statistical differences between the highly motivated students for pre-CU and pre-SR, with F ratios (*2, 117*) of 1.653 (p = .196) and 1.700 (p =.187), respectively. Also, the results indicated that there were no significant statistical differences between the low-motivation students in pre-CU and pre-SR, with F ratios (2,117) of 2.803 (p = .65) and 1.625 (p = .201), respectively. This means that there were no statistically significant differences between highly motivated students and low-motivation students across the three groups for pre-CU and pre-SR. Therefore, the assumption that the highly motivated participants across the three groups and the low-motivation participants across the three groups are equivalent in terms of conceptual understanding and scientific reasoning was found to be correct.

Table 4. Summary of multivariate analysis of variance (MANOVA) pre-CU and pre-SR results and follow-up analysis of variance (ANOVA) results

	MANOVA Effect and Dependent Variables	Multivariate F	Univariate F df = 2,117
	Group Effect	Pillai's Trace 1.773 (*p* =.135)	
Highly Motivated (HM)	Pre-Conceptual Understanding Pre-CU		1.653 (*p*=.196)
	Pre-Scientific Reasoning Pre-SR		1.700 (*p*=.187)
	Group Effect	Pillai's Trace 2.255 (*p*=.064)	
Low-Motivation (LM)	Pre-Conceptual Understanding (pre-CU)		2.803 (*p* =.065)
	Pre-Scientific Reasoning (Pre-SR)		1.625 (*p* =.201)

The experimental study results

The purpose of the experimental study was to examine the effects of the instructional methods on conceptual understanding (CU), and scientific reasoning (SR)—specifically, on highly motivated and low-motivation students' conceptual understanding and scientific reasoning—while controlling students' pre-CU and pre-SR from the pre-test. A two-way multivariate analysis of covariance (MANCOVA) was conducted to analyze the effects of the instructional method on the two dependent variables and the interaction between the instructional methods' and the motivational levels' effects on the two dependent variables.

The statistical differences between the three groups were determined and analyzed according to each of the two dependent variables. The research hypotheses were tested using the results of the two-way multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). The results of the analysis were used to answer Research Questions 1-4.

Testing of hypothesis 1

Students taught via cooperative learning with the Dual Situated Learning Model (CLDSLM) will perform higher than students taught via the Dual Situated Learning Model (DSLM) instructional method—who, in turn, will perform higher than students taught via the traditional (T) instructional method in terms of (a) conceptual understanding (CU) and (b) scientific reasoning (SR). Thus, H_{01}: there is no significant difference in the mean scores for conceptual understanding performance (CU) and scientific reasoning (SR) performance between students taught via the CLDSLM instructional method, students taught via the DSLM instructional method and students taught via the T instructional method. (Xa=Xb=Xt).

Table 5 presents overall means, standard deviations, adjusted means, and standard errors for each dependent variable by instructional method: CLDSLM, DSLM, or T.

Table 5. Means, standard deviations, adjusted means and standard errors for each dependent variable by instructional method

Dependent Variables		Instructional Method		
		CLDSLM N = 80	DSLM N = 79	T N = 81
Conceptual Understanding (CU)	Mean	17.6500	16.5570	15.7654
	SD	2.3390	2.7351	2.2928
	Adj.mean	17742^a	16.611^a	15.639^a
	Std. Error	.156	.157	.155
Scientific reasoning	Mean	15.1500	13.1646	11.7284

(SR)	SD	2.2842	2.7336	2.3875
	Adj.mean	15.289[a]	13.184[a]	11.576[a]
	Std. Error	.146	.147	.145

Note. Evaluated at covariates appeared in the model: pre-CU = 9.1417, pre-SR = 4.5250. Total score for CU = 22 and total score for SR = 22.

To examine if there were statistically significant differences in conceptual understanding and scientific reasoning, the adjusted mean scores of the CLDSLM, DSLM, and T groups were determined, while controlling the pre-CU and the pre-SR, via a multivariate analysis of covariance (MANCOVA).

Table 6 presents the results of the multivariate analysis of covariance (MANCOVA), showing overall differences based on the independent variable of the instructional method effect and the two dependent variables while controlling the pre-CU and pre-SR. The Pillai's Trace was used to evaluate the multivariate (MANCOVA) differences. The results of the MANCOVA analysis comparing the three groups were statistically significant ($F = 45.575$, $p = .000$). The covariates pre-CU ($F = 14.020$, $p = .000$) and pre-SR ($F = 15.553$, $p = .000$) had significant effects. Thus, the type of instructional method does significantly influence students' scientific reasoning (SR) and conceptual understanding (CU) of heat after a significant adjustment of group's means for the dependent variables due to differences in pre-SR and pre-CU.

Furthermore, the results of the univariate ANCOVA tests, which are presented in Table 6, indicated that there were statistically significant differences between the two dependent variables (CU, and SR). The F ratio of CU (2, 237) was 44.600 ($p = .000$). This means that the instructional method had a main effect on CU. This effect accounted for 28% of the variance in CU ($\text{Eta}^2 = .282$). The F ratio of SR (2, 237) was 161.490 ($p = .000$). This means that the instructional method had a main effect on SR. This effect accounted for 58% of the variance of SR ($\text{Eta}^2 = .583$).

Table 6. Summary of the multivariate analysis of covariance (MANCOVA) results by instructional method and follow-up analysis of variance (ANOVA) results

MANCOVA Effect, Dependent Variables And Covariate	Multivariate F Pillai's Trace	Univariate F df = 2,237
Group Effect	45.575 (*p* =.000)	
Conceptual Understanding (CU)		44.600 (*p* =.000)
Scientific Reasoning (SR)		161.490 (*p* =.000)
Pre-CU	14.020 (*p* =.000)	
Pre-SR	15.553(*p* =.000)	

The results of the MANCOVA analysis comparing the three groups for the two dependent variables indicated that there were statistically significant differences between two groups for the dependent variables. Therefore, the researcher further investigated the univariate statistics results (an analysis of covariance ANCOVA) by performing a post hoc pairwise comparison using the /lmatrix command for each dependent variable to identify where the differences in the adjusted means lay. Table 7 is a summary of post hoc pairwise comparisons.

Table 7. Summary of post hoc pairwise comparisons

	Dependent Variable			
Comparison Group	Conceptual Understanding (CU)	Sig	Scientific Reasoning Adj. Mean Difference	Sig
CLDSLM vs.	1.131	.000	2.105	.000

DSLM				
CLDSLM vs. T	2.103	0.000	3.713	.000
DSLM vs. T	.972	.000	1.608	.000

*Note***.** The adjusted mean differences shown in this table are the subtraction of the second condition (on the lower line) from the first condition (on the upper line); for example, 1.131 (Adjusted Mean Difference for Conceptual Understanding) = CLDSLM – DSLM.

Table 5 displays the means, standard deviations, adjusted means and standard errors of different conditions by the dependent variables. Table 6 and table 7 show that there are differences between the statistical adjusted means for the three conditions and the two dependent variables. The adjusted mean differences are presented below.

Conceptual Understanding

The cooperative learning with Dual Situated Learning Model (CLDSLM) group (Mean = 17.7, SD = 2.3, Adj.mean = 17.7, p = .000) significantly outperformed the other two groups (DSLM and T), with an adjusted mean difference of 1.131 and 2.103, respectively. On the other hand, the Dual Situated Learning Model (DSLM) group (Mean = 16.6, SD = 2.7, Adj.mean = 16.6, p = .000) significantly outperformed the control group (T) (Mean = 15.8, SD = 2.3, Adj. mean = 15.6), with an adjusted mean difference of .972. (Effect sizes on CU were .47 and .34 comparing the CLDSLM group with the DSLM group and the DSLM group with the T group, respectively).

Scientific reasoning

The CLDSLM group (Mean = 15.2, SD = 2.3, Adj.mean = 15.3, p = .000) significantly outperformed the DSLM and T groups, with adjusted mean differences of 2.105 and 3.713, respectively. The DSLM group (Mean = 13.2, SD = 2.7, Adj.mean = 13.2, p = .000) significantly outperformed the T group

(Mean = 11.7, SD = 2.4, Adj.mean = 11.6) with an adjusted mean difference of 1.608. (Effect sizes on CU were .83 and .60 for comparing the CLDSLM and DSLM, and DSLM and the T group, respectively).

Summary of testing hypothesis 1 (CLDSLM > DSLM > T)

The statistical results confirmed the hypothesis, showing that students taught via cooperative learning with the CLDSLM instructional method performed significantly better than students taught via the DSLM learning instructional method—who, in turn, performed significantly higher than the students taught via the traditional instructional method T in terms of (a) conceptual understanding and (b) scientific reasoning.

Testing of hypotheses 2

There are interaction effects between instructional methods and motivation levels (highly motivated and low-motivation) for conceptual understanding and scientific reasoning.

Table 8 presents overall means, standard deviations, adjusted means, and standard errors for the different dependent variables by the interaction between instructional methods and motivation levels (high-motivated and low-motivated).

Table 8. Means, standard deviations, adjusted means and standard errors for each dependent variable by the interaction between instructional methods and motivation levels (highly motivated and low-motivation)

Dependent Variables		Conceptual Understanding (CU)	Scientific Reasoning (SR)
	Motivation		
Instructional Method	Highly Motivated (HM) Low-Motivation (LM)		

CLDSLM	HM (n = 40)	Mean	19.4500	16.8000
		SD	1.6939	1.8701
		Adj.mean	18.681[a]	15.745[a]
		Std.Error	.266	.249
	LM (n=40)	Mean	15.8500	13.5000
		SD	1.2517	1.2195
		Adj.mean	16.802[a]	14.833[a]
		Std.Error	.285	.267
DSLM	HM (n = 38)	Mean	19.000	15.5526
		SD	1.2945	1.4275
		Adj.mean	17.997[a]	14.155[a]
		Std.Error	.296	.277
	LM (n=41)	Mean	15.8500	10.9512
		SD	1.2517	1.4992
		Adj.mean	15.226[a]	12.213[a]
		Std.Error	.287	.269
T	HM (n = 42)	Mean	17.4286	13.6190
		SD	1.6101	1.4808
		Adj.mean	16.545[a]	12.430[a]
		Std.Error	.279	.262
	LM (n = 39)	Mean	13.9744	9.6923
		SD	1.3858	1.1955
		Adj.mean	14.734[a]	10.723[a]
		Std.Error	.269	.252

Note. Evaluated at covariates appeared in the model: pre-CU = 9.1417, pre-SR = 4.5250. Total score for CU = 22 and total score for SR = 22.

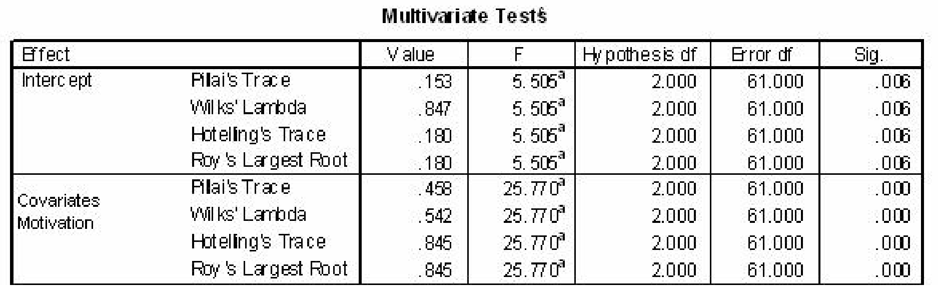
To examine if the effects of instructional method on conceptual understanding and scientific reasoning depend on the motivation levels in the CLDSLM group, the DSLM group, and the T group, while controlling for pre-CU and pre-SR, a two-way multivariate analysis of covariance (MANCOVA) was conducted.

Table 9 presents the results of the two-way multivariate analysis of covariance (MANCOVA), showing overall differences in the interaction between instructional method and motivation level in their effect on the two dependent variables while controlling for pre-CU and pre-SR. Pillai's Trace was used to evaluate the multivariate (MANCOVA) differences. The MANCOVA results for the interaction effects on the two dependent variables were statistically significant (*F* = 4.836, *p* = .000). The covariates pre-CU (*F* = 14.020, *p* = .000) and pre-SR (*F* = 15.553, *p* = .000) had significant effects. This means that there were some statistical interaction effects on at least one dependent variable across the three groups.

Furthermore, the results of the two-way univariate ANCOVA tests, which are represented in Table 9, indicated that there were statistically significant interaction effects across the three groups in SR. The *F* ratio of SR (2,237) was 3.401 (*p* = .035). This means that the interaction effect was statistically significant for students' SR. This interaction accounted for 3% of the variance in the students' SR ($\text{Eta}^2 = .028$). However, there were no statistically significant interaction effects across the three groups in CU. The *F* ratio of CU (*2*, *237*) was 2.917 (*p* > .05).

Table 9. Summary of the results of the multivariate analysis of covariance (MANCOVA) results by the interaction effect and follow-up analysis of covariance (ANCOVA) across the three groups

MANCOVA Effect, Dependent Variables, And Covariate	Multivariate F Pillai's	Univariate F Df = 2,237
Group Effect	4.836 (*p* =.000)	
Conceptual Understanding (CU)		2.917 (*p* =.056)
Scientific Reasoning (SR)		3.401 (*p* =.035)
Pre-CU	14.020(*p* =.000)	
Pre-SR	15.553 (*p* =.000	



Multivariate Tests^{b}

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.153	5.506^{a}	2.000	61.000	.006
	Wilks' Lambda	.847	5.506^{a}	2.000	61.000	.006
	Hotelling's Trace	.180	5.506^{a}	2.000	61.000	.006
	Roy's Largest Root	.180	5.506^{a}	2.000	61.000	.006
Covariates Motivation	Pillai's Trace	.458	25.770^{a}	2.000	61.000	.000
	Wilks' Lambda	.542	25.770^{a}	2.000	61.000	.000
	Hotelling's Trace	.845	25.770^{a}	2.000	61.000	.000
	Roy's Largest Root	.845	25.770^{a}	2.000	61.000	.000

The two-way MANCOVA results regarding the interaction effects on SR indicated that there were statistically significant interaction effects between the instructional method and the students' motivation level in at least one group. Therefore, the researcher further investigated the interaction effect results by plotting the interaction between the instructional method and the students' motivation level on SR to identify where the significant interactions resided. Also, the interaction between the instructional method and the students' motivation level on CU is plotted. Fig. 2 shows the interaction effect of the instructional method and the students' motivation level across the three groups on CU.

Fig. 2 show that there is no interaction effect of the instructional method and the students' motivation level on CU across the three groups. In other words, highly motivated and low-motivation students taught via the CLDSLM, DSLM, and T instructional methods benefited equally in terms of conceptual understanding. Therefore, the effect of the instructional methods on CU did not depend on the motivation level.

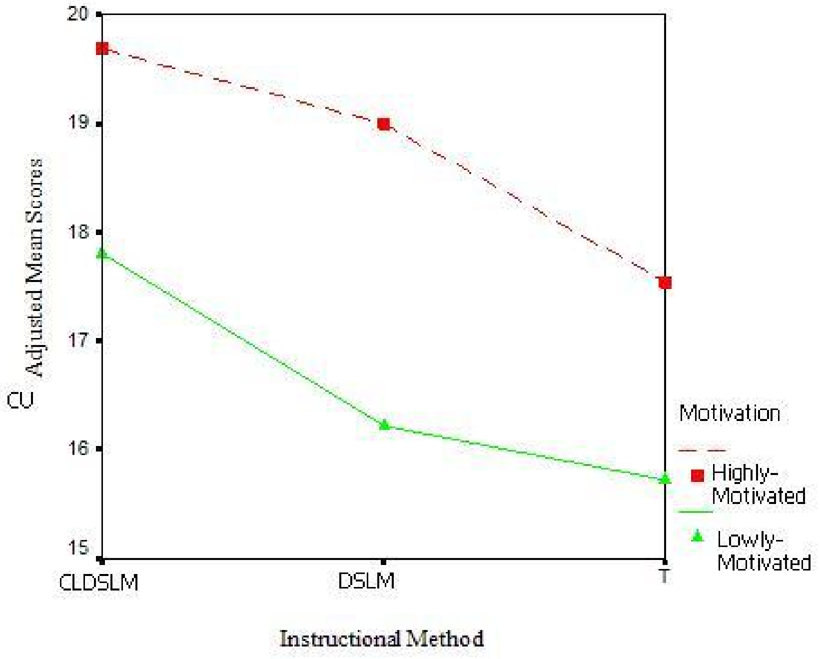


Fig. 2. Interaction effect between the instructional method and the students' motivational levels on CU

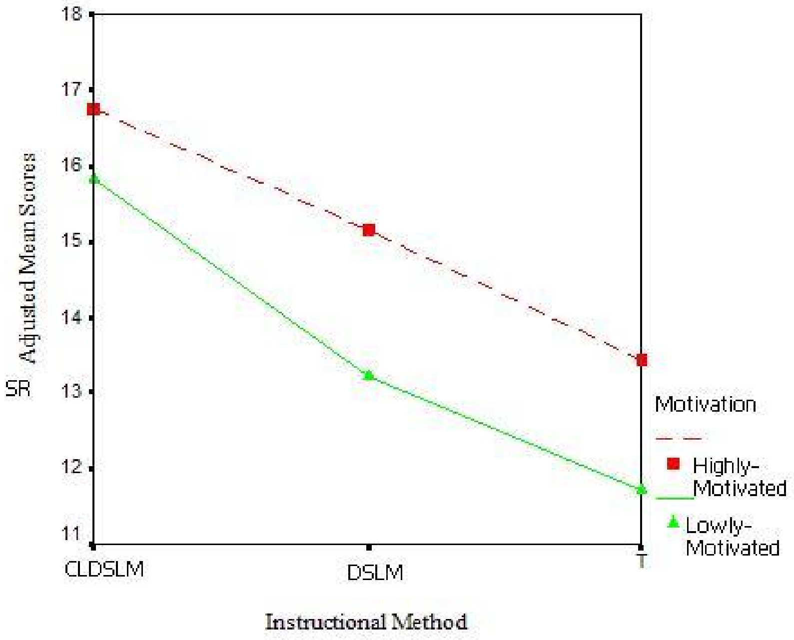


Fig. 3. Interaction effect of the instructional method and the students' motivation levels on SR

Fig. 3 shows that the low-motivation students taught via the CLDSLM instructional method benefited more than the highly motivated students taught via the same instructional method in terms of scientific reasoning. However, the figure shows that the highly motivated and low-motivation students taught via the DSLM and T instructional methods benefited equally in terms of scientific reasoning.

Summary of testing hypotheses 2

(There are interaction effects between the instructional methods and the ability levels). The statistical interaction results and the interaction figures partially confirm the hypotheses, showing that there were interaction effects between the CLDSLM instructional method and the motivational levels where low-motivation students benefited more than the highly motivated students in terms of SR but benefited equally in terms of CU. There were no interaction effects for the DSLM instructional method and the motivation level. That is, the performance of the DSLM instructional method did not depend on the motivation level. Highly motivated and low-motivation students taught via the DSLM instructional method benefited equally in terms of CU and SR. Finally, there were no interaction effects for the T instructional method and the motivational levels. That is, the performance of the T instructional method did not depend on the motivation levels. Highly motivated and low-motivation students taught via the T instructional method benefited equally in terms of CU and SR.

Summary and conclusions

This study found that the use of cooperative learning helped students to fully benefit from the Dual Situated Learning Model (DSLM). Overall, the CLDSLM group outperformed the DSLM group for all measures, showing that for form four physics, the Dual Situated Learning Model alone was not sufficient as a form of teaching scaffolding.

The low-motivation students taught via the CLDSLM method outperformed their counterparts taught via the DSLM and T methods in conceptual understanding and scientific reasoning. The low-motivation students taught via the DSLM method in turn outperformed their counterparts taught via the T method in scientific reasoning (SR) but not in conceptual understanding (CU).

This study shows that the Dual Situated Learning Model (DSLM) learning method, when embedded with jigsaw cooperative learning scaffolding and implemented correctly in the classroom, is an effective method in helping low-motivation students learn physics with understanding and reason scientifically.

The high-motivation students taught via the CLDSLM method outperformed their counterparts taught via the DSLM method in scientific reasoning (SR) but not in conceptual understanding (CU) and outperformed their T method counterparts in CU and SR. The highly motivated students taught via the DSLM method, in turn, outperformed their counterparts taught via the T method in terms of conceptual understanding and scientific reasoning.

The CLDSLM method was highly effective in teaching conceptual understanding for both highly motivated and low-motivation students, but the interaction effects showed that the CLDSLM method is very effective for enhancing scientific reasoning among low-motivation students.

From these findings, it can be concluded that the use of cooperative learning helped the students to fully benefit from the Dual Situated Learning Model. When students are actively engaged in activities in stage 5 (that is, instructing with learning events) that emphasize giving students an opportunity to make predictions, provide explanations, confront dissonance, and construct a more scientific view of concepts, they benefit much from the Dual Situated Learning DSLM learning process. Therefore, the DSLM learning method is inadequate without cooperative learning, or DSLM learning with the cooperative learning method is superior to the DSLM learning method alone. It follows that the DSLM learning process should be scaffolded appropriately through cooperative learning. The DSLM is especially effective in improving students' scientific reasoning. The DSLM method with cooperative learning scaffolding is effective at improving student performance in all aspects of physics. The DSLM method with cooperative learning, furthermore, is an effective method across motivation levels but is especially beneficial for low-motivation students.

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