The Convergence of Mayer's Model and Constructivist Model towards Problem solving in Physics

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Abstract
This study investigated the convergence of the Mayer's model and constructivist model towards problem solving in Physics. Twenty six students in Physics 1 (University Physics 1) enrolled in the third trimester, SY 2011 – 2012, were used as subjects of the study. An analysis of the students' learning history in College Algebra and Trigonometry was conducted as basis of determining their mathematical abilities. A pre-test was conducted to determine the initial learning schema of the respondents. The examination used as pre-test was formulated by the author as his output in his dissertation and was field tested to a group of students majoring in Science at Quirino State College, Philippines. The Mayer's model was used as a default procedure followed by the four-stage constructivist model in problem solving. Students were engaged in active learning through direct instruction using the Mayer's model from the teacher, small group discussion, peer mentoring and follow-up session/s by the teacher vis-à-vis with the four-stage constructivist model in problem solving. Analysis of transcripts was done to determine the extent of learning of the respondents and the remediation to be implemented. After the execution of the lessons, the students were given a post-test. It was found out that the students who were exposed to the convergence of the Mayer's model with the constructivist model developed better attitudes and performance in problem solving. A significant effect and a moderately high impact model of variability on the attitude and academic performance of the students: 85.2 % on the students' attitude towards problem solving and 80.00 % on the students' academic performance.
Keywords: Constructivist Model for Teaching Word Problem, Learning Attitudes, Learning Ability, Mathematical Discourse, Mayer's Model in Problem Solving

1. The Problem and Its Background

Problem solving in Physics, as influenced by cognitive learning theories, is mystified as difficult over the years as students hold negative stereotype images towards the subject (Changeiywo, 2000; Bautista, 2004 & 2008; Wangbugu & Changeiywo, 2008). This calls for a sound technique of decontextualized set of skills on convergent reasoning in engaging students to higher cognition activities towards the subject.

Techniques in solving problems are key objectives in Physics as problems are unavoidable. It involves attitudinal as well as cognitive components of the problem solving process: effort, confidence, anxiety, persistent and knowledge (Jonassen and Tasmeer, 1996; Abbott and Fouts, 2003; Kim, 2005; Bautista, 2012). Hence, students need to consider and formulate suitable techniques in finding ways over problems as their successes in achieving these objectives develop positive attitudes towards problem-solving.

Researches had been conducted on the importance of a student's attitude towards learning problem solving. It was articulated well that the achievers in word problem solving are the students who have developed positive attitudes in it. Concomitantly, these tend to give outstanding performances not only in learning problem solving but in education as a whole (Papanastasiou, 2000; Lopez & Sullivan, 1992; Ross & Anand, 1987; Ku & Sulivan, 2002; Jenkins and Keefe, 2005; Smutny, 2003; Nordlund, 2003; Jasmin, 2005; Bautista, 2005, 2008 & 2012).
Apparently, strokes as to how to teach problem solving had been prevalent since time immemorial: Mayer, Polya, among others, had successfully introduced and tested by time. However, teachers, as a facilitator of students in the dynamic classroom situation, must learn how to tailor such approaches, methodologies and strategies that would suit best the need of their student-learners. Thus, the elements of the teaching-learning process must be flexible yet interactive in a constructive learning environment.

The success of the teaching-learning process depends on the input given by the teacher, the student and the learning environment. Iquin (1993) in Bautista (2005) claimed that the new type of teaching materials as well as new classroom procedures call for an alert type of the teacher whose role includes a follow up of the learning made by his students. This alleviates the classroom routines in relation to the didactic triangle of Physics instruction: Teachers, Knowledge and Students (Lave, 1988; Brown, Collins & Duguid, 1989; and Tiberghien, et al., 1998; Smutny, 2003; Nordlund, 2003; and Jasmin, 2005).

The crux is: Although there is no standard technique prescribed in solving a word problem, one's success in working out word problems depends largely on his ability to translate it into a functional mathematical models for inquiry.

In view of the foregoing, this study elaborates the articulation of the contemporary initiatives in a dynamic classroom environment. It focuses on learning the history of learners including their learning styles, and the culture of collegiality in the learning environment. It further presents the constructive learning environment as a mitigating factor in the development of a sound culture of learning and development in the course; the role of collaborative learning making it interactive and cooperative to learners in a shared culture of active learning experiences through small group discussion (SGD), teacher-coach-adviser and peer-mentor (Cobb, Stephan, McClain, & Gravemeijer, 2001; Lerman, 2001; Cordova & Lepper, 1996; Lopez & Sullivan, 1992; Ross & Anand, 1987; Ku & Sulivan, 2002; Jenkins and Keefe, 2005; Smutny, 2003; Nordlund, 2003; Jasmin, 2005; and Bautista, 2005).

It is in this context that the teacher's role in facilitating learning is significantly desirable because a teacher who is aware of his role in the teaching-learning process does not only depend on the printed words in books. Rather, he designs his own routines and supplementary materials. He is expected to equip his students with instructional materials that contain the most effective and constructive ways to develop skills and enrich their learning (Bautista, 2008). Thus, enhancing the Mayer's model in its convergence with the constructivists model in teaching problem solving to find out its effects in the morale and ability of the learners in doing such learning tasks in the subject.

1.1 Model for Teaching Problem Solving

Figures 1 depicts the model for teaching problem solving using the Four-Stage Constructivist Model (Kheong and Hsui, 1999). Kheong and Hsui (1999) in Petilos (2003) tested a four-stage constructivist model for teaching mathematical problem solving. The model as shown in Figure 1 views the construction of knowledge as central to the learning of specific problem-solving processes (or strategies) in Mathematics. It consists of a four-stage guide, with steps 2 (*Transmission*) and 3 (*Construction*) of pivotal importance in learning problem-solving and the construction of mathematical knowledge among the learners.

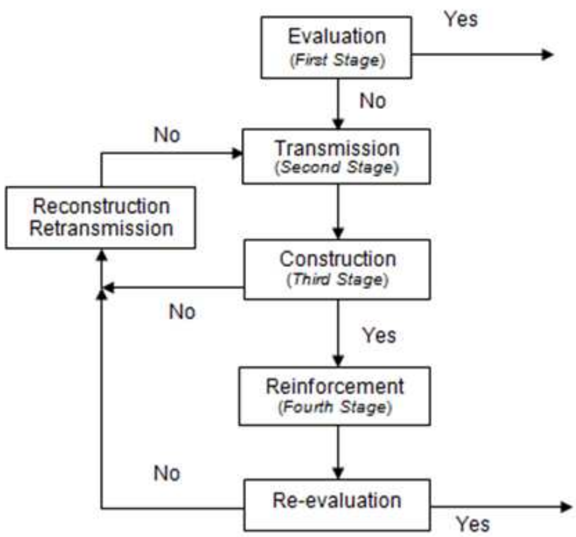

Figure 1. Four-Stage Constructivist Model for Teaching Problem Solving (Kheong and Hsui, 1999)

In this model, the *Evaluation* stage is the diagnostic stage where the learners are assessed to see if they have already mastered the target problem-solving process(es). Specific diagnostic mathematical problems are assigned for this purpose. If the students have not mastered the processes, they will move to the second stage of the instructional process which is the *Transmission* stage. Through discussion, the learners, in interaction with the teacher, attempt to construct the target problem solving process by tackling the same problem again without reference to the given solution. At this stage, the students have the opportunity to clarify errors or misconceptions in interaction with the teacher.

Next, during the *Construction* stage, learners are asked to solve the same problem again without looking at the given solution and without help from the teacher or peers. At this stage, the students have the opportunity to construct the concepts which may not have been fully understood in the transmission stage by recalling, relating and reflecting on what they have learned in the previous stage. In the construction stage, the learners may reorganize their ideas and accommodate some of the new ideas into their existing concepts in solving the problem.

If the students are able to solve the problem independently, they will exit from the *Construction* stage and will be given tasks for the fourth stage. However, if they have difficulty or they make errors in solving the problems independently, they will undergo another round – retransmission and reconstruction – to ensure mastery in the construction of the target problem-solving process.

The students will exit from the *Construction* stage if they are found to have mastered the intended knowledge or target problem-solving procedures by succeeding in solving the target problem independently.

It is in this context that eclectic methodologies and approaches are to be integrated in the mathematical discourse used in the theory room: the use of modeling, meta-cognition, buzz groups and buzz sessions towards cooperative learning, motivation, among others, are to be analyzed and investigated as a way of converging the Mayer's model of problem solving and constructivist model in teaching problem solving in Physics.

1.2 Objectives of the Study

This study was designed to discern the effects of the convergence of the Mayer's model and constructivist model in teaching problem solving in Physics with various methodologies, approaches and motivation schemes offered in a constructive learning environment.

Specifically, it sought to find the explanations of the following:

1. What are the students' attitude towards problem solving skills in the experimental and control group?
2. Is there a significant difference in the attitude of the students in the experimental and control group towards problem solving before and after the experiment?
3. What are the problem solving skills of the students in the experimental and control group in terms of:
   3.1 Problem Translation;
   3.2 Problem Integration;
   3.3 Solution Planning and Monitoring; and
   3.4 Solution Execution.
4. What is the level of achievement in Physics of the students in experimental and control group?
5. Is there a significant difference in the level of achievement of the students in Physics between the experimental and control group?
6. Is there a significant interaction between the method and ability of the students towards the subject?

1.3 Research Paradigm

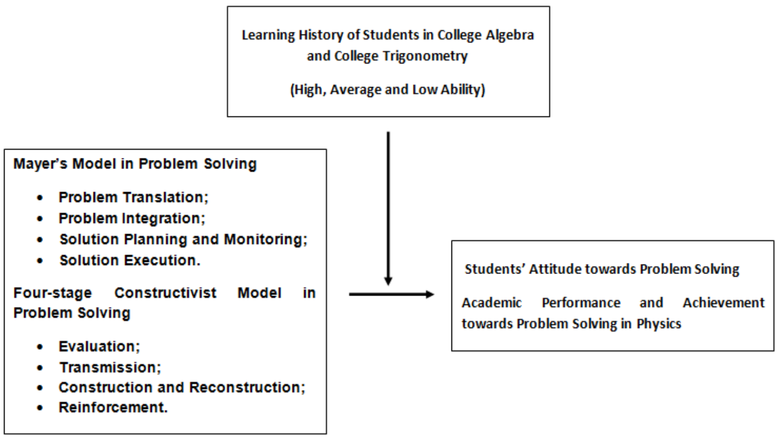

Figure 2. Research Paradigm

Figure 2 presents the research processes in this study especially the relationship of the independent and dependent variables and the impact of the intervening variables in the observance of the dependent variable. This study used two important independent variables: the Mayer's model and the four-stage constructivist model in problem solving. The control group received only the Mayer's model which was used in the study as a default teaching model towards problem solving. On other hand, the experimental group received the converging models of Mayer with the four-stage of constructivist model in problem solving together with eclectic methodologies in creating a constructive learning environment.

The learning history of students in College Algebra and College Trigonometry are believed as potential variable in the success of the students in Physics as it is taught thoroughly in an array of mathematical points of view. Their knowledge and skills in problem solving which are developed in Mathematics are of great implication especially on the peculiarities of problems both in science, engineering and industry.

This manipulation and contraventions on the learning experiences of the students are believed to reshape their attitude and academic achievement towards problem solving in physics as it had been mystified as difficult since time immemorial.

2. Methodology

The Quasi-Experimental Design (pretest-posttest control group design) was used in this study. This provided bases for the causal effect of the independent variables to the dependent variable involving experimental and control groups. Treatment (integration of eclectic methodologies and approaches on the convergence of the Mayer's model and a four-stage constructivist model for teaching problem solving) was introduced in the experimental group. The discourse treatment was limited only in the development of Mathematical Concepts, Kinematics, Statics and Heat. Modeling of the eclectic methods and approaches was integrated in the discourse treatment as well as reinforcement strategies based on social constructivism model. The use of groupings and motivation was introduced in the process. Analysis of the scores was done to conclude on the causal effect of the independent variable.

On the other hand, the customary instruction – Mayer's model based instruction, was made to the control group with the usual class session, ordinary assignment and individual seatwork and problem set.

Two sections in NATSC1D (University Physics 1) handled by the author during the 3rd trimester, SY 2011 – 2012, was used as subjects of the study. Lottery was used in determining the experimental groupings of the study.

Table 1. Respondents of the Study

Mathematical Ability	Experimental	Control	Total	Percent (%)
High ability	5	3	8	30.77
Average Ability	2	6	8	30.77
Low Ability	7	3	10	38.46
Total	14	12	26	100

Range: High – 1.75 – 1.00; Average – 2.50 – 1.76; Low 3.00 – 2.49

Table 1 presents the profile of the respondents as to their mathematical abilities based on their average in College Algebra and College Trigonometry. It presents that majority of the respondents are lowly able in Mathematics with 10 or 38.46 % of the entire respondents, while both high and average mathematical abilities have 8 or 30.77 % of the respondents. It can be said that the groups of respondents are heterogeneous. Furthermore, it can also be inferred that the groups need a constructive learning environment for them to be assisted in their learning tasks and experiences in the subject.

There were two instruments used in this study: An Attitude Inventory Survey and Achievement test.

Attitude Inventory. This study used the attitude inventory which was formulated by the researcher and was validated by the some faculty members of the Mathematics Department. It was then translated in Arabic to make each item understandable to the respondents. It was based on the attitude inventory obtained from Mathematical Problem Solving Project at Indiana University (Charles et al., 1997). Items' reliability contained in the Attitude Inventory was determined through the Cronbach alpha's reliability coefficient. Cronbach's alpha generally increases as the inter-correlations among test items increases, and is thus known as an internal consistency estimate of reliability of test scores (Wikipedia, 2011) http://en.wikipedia.org/wiki/Cronbach's_alpha. It was found out that the coefficient of the indicators contained in the inventory was 0.83 for willingness, perseverance, self-confidence and motivation, respectively. According to Konting (2004), an alpha value that exceeds 0.6 signifies acceptable reliability.

Achievement Test in Physics. The instrument used in this study was a validated twenty (20) items teacher-made achievement test, developed by the researcher (Dissertation output: 2008), in Physics 11 covering topics in Mathematical Concepts, Mechanics and Heat as determined by a Table of Specification (TOS) based on the CMO 32 as the blueprint of the subject. The validation and refinement was conducted at the Secondary Teacher Education Program, Teacher Education Institute, Quirino State College, Diffun, Quirino, Philippines, where the author was previously employed as Instructor.Items were analyzed using the chronbach's alpha. Reliability contained in the Achievement Test was determined with a coefficient reliability of 0.87. This means that the inter-correlations among the items in the test are of consistent and indicate that the degree to which the set of items measured a unidimensional latent construct. Rubric assessment was formulated to determine the extent of skills mastered by the students based on Mayer's model.

The mean, standard deviation, Cronbach alpha's reliability coefficient, Levene's test for equality of variance, t-test, ANOVA and the ANCOVA were used in this study.

3. Result and Discussion

Table 2. Students' Attitude towards Problem Solving

	Attitudes towards Problem-solving	Experimental Group		Composite		Control Group		Composite	
		Pre	Post	Mean	D.I.	Pre	Post	Mean	D.I.
1	Willingness	3.729	3.986	3.858	A	3.517	3.750	3.634	A
2	Perseverance	3.657	4.086	3.872	A	3.733	3.633	3.683	A
3	Self-confidence	3.743	3.929	3.836	A	3.683	3.500	3.592	A
4	Motivation	3.757	3.943	3.850	A	3.450	3.767	3.609	A
	Average	3.722	3.986	3.854	A	3.596	3.663	3.630	A

* Legend: A – Agree

Table 2 presents the comparison of the students' attitude towards problem solving when grouped according to inventory sessions and general inventory. It shows that both the experimental and control groups *Agreed* on the prevalence of the items contained in each indicator of the attitude inventory: over all mean of 3.854 and 3.630 for the experimental and control groups, respectively.

Table 3. Test of Difference on the Students' Attitude towards Problem Solving

Indicators	Pre-test			Post-test		
	t	df	Sig (2-tailed)	t	df	Sig (2-tailed)
Willingness	0.954	21.709	.350	1.225	20.222	.234
Perseverance	-0.308	23.834	.760	2.423	24	**.023***
Self-confidence	0.222	23.646	.826	2.213	18.341	**.040***
Motivation	1.327	21.899	.198	0.725	23.334	.476

* Significant at 0.05 level of significance

Presented in table 3 is the test of difference on the students' attitude on the two inventory sessions. It presents the test results on the students' attitude inventory towards problem solving prior to the conduct of the study: t-values of 0.954, -0.308, 0.222 and 1.327, and p-values of .350, .760, .826 and .198 at 0.05 level of significance, respectively, for willingness, perseverance, self-confidence and motivation. This means that there is no significant difference on their attitude towards problem solving prior to the conduct of the study. Hence, the null hypothesis is accepted.

Apparently, there are significant differences on the attitudes of the students with regards to perseverance and self-confidence in favor of the experimental group: t-values of 2.423 and 2.213, and p-values of .023 and .040 at 0.05 level of significance, respectively. Hence, the null hypothesis is rejected.

On the other hand, no significant difference is observed on willingness and motivation: t-values of 1.225 and 0.725, and p-values of .234 and .746 at 0.05 level of significance, respectively. Hence, the null hypothesis is accepted.

It can be construed that willingness emanates from the motivation drive of the student developed within him. This phenomenon can be explained by the Attitude-Behavior Consistency Theory of Kallgren and Wood (1986) and the Cognitive Evaluation Theory of Deci and Ryan (1991). Kallgren and Wood theorized that attitude (predispositions to behavior) and actual behaviors are more likely to align when both attitude and behavior are both constrained to circumstances that happened in the past. Attitudes, that drives motivation, is held strongly around core beliefs. On the other hand, Deci and Ryan theorized that motivation given to a student-learner must fall within his current level of competency; that a person completes a task based on his internal and external locus of control as Physics is a potpourri of scientific concepts and had been mystified as difficult since time immemorial (Jonassen and Tasmeer, 1996; Changeiywo, 2000; Bautista, 2004; 2008; Wangbugu & Changeiywo, 2008).

Table 3.1. Test of Between-Subjects Effects on the Students' Attitude

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.851[a]	2	2.425	72.752	**.000***
Experimental Grouping	.344	1	.344	10.306	**.004***
Total	388.313	26			

a. R Squared = .864 (Adjusted R Squared = .852)

* Significant at 0.05 level of significance

Presented in table 3.1 is the two-way analysis of covariance of the attitude inventory conducted between the two groups of the study. It shows that the mean composite score obtained by the students in the experimental group is highly significantly higher than the mean composite score of the control group (F-value = 10.306 and p-value of 0.004, and a p-value of < 0.001 for the corrected model). This means that the students under the experimental group who experienced the converging model of Mayer with the four-stage of social constructivism developed better attitudes towards problem solving after the method was introduced in their learning experiences and became a potent mechanism in their learning routine.

The null hypothesis of no significant difference between the mean attitudes of the students towards problem solving exposed to the Mayer's model and the converging Mayer's model with the four-stage social constructivist model in problem solving, is hereby rejected.

It can be noted, however, that the impact of the converging models of Mayer and the Social Constructivism is high considering that the coefficient of determination indicated by the adjusted R-squared is 0.864. This means that the models of teaching account for 85.2% of the variability in the manifestation of positive attitude towards problem solving. This result is similar to the findings of Kheong and Hsui (1999), Petilos (2003), Abbott and Fouts (2003), Kim (2005) and Bautista (2008 & 2012) when they concluded that social constructivism is an effective tool in developing esteem among learners as there is synergy in their interaction with their peers and teacher-coach adviser.

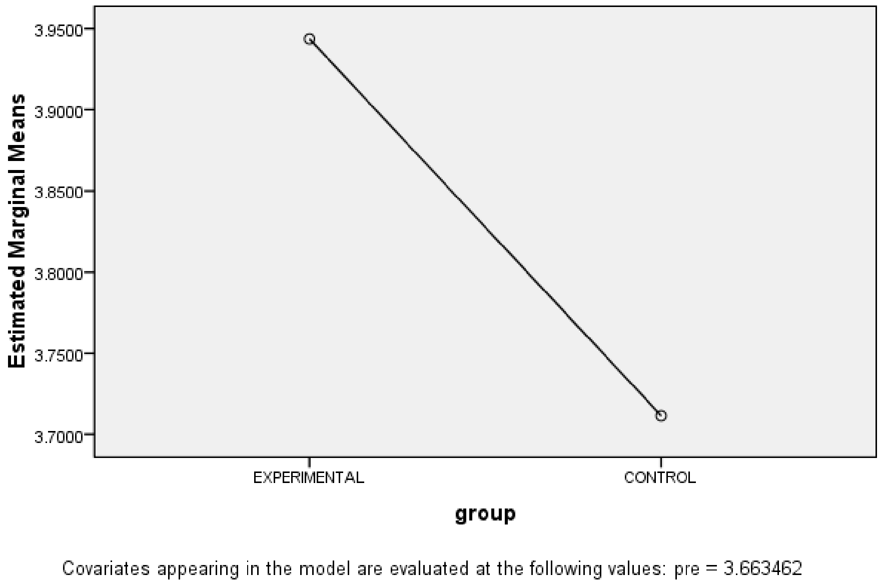

Figure 3. Estimated Marginal Means of the Post-attitude Inventory

Figure 3 presents the relationship of the estimated marginal means of the post-test result and the groupings of the study, the experimental and control group. The result of the post-test mean score is evaluated with the pre-test covariate value of 3.663462.

The results of the study indicate that students who were exposed to the converging methods of Mayer and the four-stage Social Constructivism towards problem solving obtained a significantly higher mean post-test score on their attitude inventory than the students who were only exposed to the Mayer's model. This result supports the findings obtained by Schafersman (1991), Gokhale (1995), Mevarech (1999), Kheong and Hsui (1999), Petilos (2003), Abbott and Fouts (2003), Kim (2005) and Bautista (2004, 2008 & 2012) who reported that the students in the collaborative learning group posted better scores on the critical thinking test than students who studied individually. Thus, they developed better attitude towards problem solving.

Table 4. Problem Solving Skills of the Students

Chapter Test		Groups		Composite	
		Experimental	Control	Mean	Interpretation
1	Mathematical Concepts	2.994	3.181	3.088	SPM
2	Mechanics	2.672	2.127	2.400	PI
3	Heat	3.399	3.465	3.432	SPM
	Average	3.022	2.924	2.973	SPM

Legend: (PT) Problem Translation; (PI) Problem Integration; (SPM) Solution Planning and Monitoring; (SE) Solution Execution

Presented in table 4 are the general problem-solving skills of the students in the three major topics covered in this study. Using the chapter test result and the Mayer's model in problem-solving as a reference, the students' skills towards problem-solving were identified.

It was found out that the students' problem solving skills fall under *Solution Planning and Monitoring Stage* with a mean score of *2.973* as they fail to execute solution strategies among convergent problems. A discriminating poor performance is observed in the development of the Mechanics part as the respondents earned a mean score of *2.400* and interpreted as *Problem Integration*. This means that the students were able to cognitively define and explore the problem but failed to master skills on convergent reasoning strategies that lead them evaluate and transfer skills to different views. It can be construed further that they failed to develop mathematical models in the establishment of a free-body diagram that will substantiate planned solutions using linguistic properties and other logico-mathematical properties.

This finding confirms the conclusion of the AMAIUB-Mathematics professors in their appraisal to the attainment of the Course Intended Learning Outcomes (CILO) in Mathematics during the 2nd trimester, SY 2011 – 2012. They inferred that the students fail to respond to higher learning outcomes as they were failures to solve convergent problems that require decontextualized reasoning strategies. Hence, reinforcement activities and programs are highly wanting as this difficulty poses threat to their academic success in higher Physics and Engineering subjects.

Table 5. Mean Scores of the Respondents in the Post-test

	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Experimental Group	10.406[a]	.568	9.218	11.595
Control Group	8.296[a]	.653	6.930	9.662

a. Covariates appearing in the model are evaluated at the following values: Pre-test = 4.85.

Table 5 presents the mean scores of the two groups of the study: 10.406 and 8.296 for the experimental and control group respectively. These results were evaluated with the covariate value of the pre-test conducted, 4.85. This means that the students in the experimental group performed better than their counterparts in the control group.

Table 6. Test of Difference on the Level of Achievement of Students

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
ected Model	355.531[a]	6	59.255	17.632	**.000***
rimental Grouping	18.504	1	18.504	5.506	**.030***
tal Ability	43.683	2	21.842	6.499	**.007***
rimental Grouping * Mental Ability	25.511	2	12.756	3.795	**.041***

a. R Squared = .848 (Adjusted R Squared = .800)
* Significant at 0.05 level of significance

Presented in table 6 is the two-way analysis of covariance of the tests conducted between the two groups of the study. It presents the causal effect of the teaching model to the academic performance of the students when grouped according to their experimental grouping and mental abilities: F-values of 5.506 and 6.499, and p-values of 0.030 and 0.007, respectively. Moreover, an interaction model of the experimental grouping and the students' mental abilities in mathematics: an F-value of 3.795 and a p-value of 0.041. This means that the students under the experimental group who experienced the converging models of Mayer and the four-stage social constructivist model of problem solving performed better in the subject after the method was introduced in their learning experiences and became a potent mechanism in their learning-routine.

The null hypothesis of no significant difference between the mean academic achievement of students exposed to the converging models of Mayer and Constructivism towards problem solving and the default Mayer's model of problem solving is, therefore, rejected. This means that constructive instruction is significantly better than the traditional model in terms of its impact on the overall academic achievement of the students.

It can be noted, however, that the impact of the models of reconstructing the instruction is moderately high considering that the coefficient of determination indicated by the adjusted R-squared is 0.848. This means that the models of teaching account for 80.00 % of the variability in the academic achievement of the students. It is construed then that there are other important variables or factors such as student ability and other classroom techniques which may explain better the difference in the academic achievement of the groups of students in the experimental and control groups.

Table 6 likewise presents the interaction between the mathematical abilities of the students and the method (treatment conditions of the converging methods of Mayer and Constructivist Model in Problem Solving). It presents the impact of the treatment conditions to the academic achievement of the students across the mathematical abilities of the students in the two groups as shown in Figure 4.

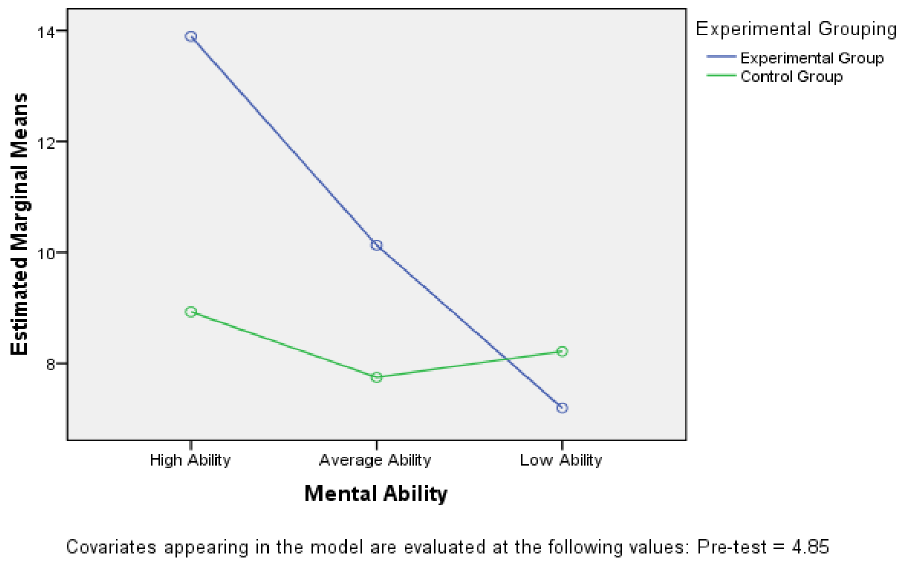

Figure 4. Estimated Marginal Means of the Post-test

Figure 4 presents the relationship of the estimated marginal means of the post-test result and the mathematical abilities of the students, categorized as low, average and high. The result of the post-test mean score is evaluated with the pre-test covariate value of 4.85. It presents that students who are highly able in Mathematics benefited the most in the program followed by the average mathematically able students. Surprisingly, the low mathematical ability group did not show a remarkable performance when compared to the low ability of the control group.

It can be construed then that there are other important variables or factors such as the students' motivation drive, other student ability, other classroom techniques, among other variables, which may explain better the difference in the academic achievement of the groups of students in both the experimental and control groups. Reinforcement activities may be aligned well for the low ability group to cope with the subject's requirement as they are academically at risk. Hence, the mastery learning approach is recommended.

In general, the results of the study indicate that students who were exposed to the constructive instruction obtained a significantly higher mean post-test score on their academic achievement than the students who were exposed to the customary teaching models and techniques. This result supports the findings obtained by Gokhale (1995), Mevarech (1999), Schafersman (1991), Petilos (2003), Abbott and Fouts (2003), Kim (2005) and Bautista (2004, 2008 & 2012) who reported that the students in the collaborative learning group posted better scores on the critical thinking test than students who studied individually. Hence, the Mayer's model in problem solving becomes more effective when it converges with constructivist teaching approach as it improves better the students' academic achievement, self-concept, and learning strategies.

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