Effects of Model-based Interactive Engagement on Problem Solving and Experimentation Abilities in Learning Introductory University Physics

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Abstract

This study was designed to test the effectiveness of model-based interactive engagement (MIE) in tutorial and laboratory classes about Newtonian mechanics course for freshman university students. It was a quasi-experimental design of non-randomized, non-equivalent pre-test post-test control group in design one and one group pretest posttest in design two. The experimental group(N = 34, M = 7, F = 24) was exposed to MIE in both designs and control group(N = 45, M = 13, F = 32) was exposed to traditional lecture method in design one. Based on the evidence which was mainly quantitative and partly qualitative and the analyses which was also done separately on both parts of the data, three research questions were answered and correspondingly three research hypotheses were tested separately in design one and design two. The result in design-one showed there was statistically significant mean difference (M.D = 4.81) with medium effect size d = 0.73 in favor of MIE. The ANOVA and independent t-test showed MIE favored male students (with M = 17.8) than female students(with M = 6.3) with $p = 0.002 < 0.05$. Pearson correlation coefficient(r = -0.256, $p = 0.158 > 0.05$) between performance test and assessment scores showed no significant correlation. The result in design-two showed there was statistically significant mean difference (M.D = 2.65) with large effect size d = 0.99. The ANOVA and independent - test showed MIE improved mean score of male students and female students with no significant difference as evident from $p = 0.1 > 0.05$. There was significant correlation between experimentation performance posttest scores and scores of the lab reports as one increased the other increased too (r = 0.531, $p = 0.028 < 0.05$). The qualitative data from questionnaire and interview of both students and teachers agrees with the findings mainly from the quantitative data except one case in design-one.

Keywords: Model-based interactive engagement, Lecture method, Basic models, Multiple representations.

Resumen

Este estudio fue diseñado para probar la efectividad del compromiso interactivo basado en modelos (MIE) en clases tutoriales y de laboratorio sobre el curso de mecánica newtoniana para estudiantes universitarios de primer año. Fue un diseño cuasi-experimental de grupo de control pre-test post-test no aleatorizado y no equivalente en el diseño uno y un grupo de pretest post-test en el diseño dos. El grupo experimental (N = 34, M = 7, F = 24) estuvo expuesto a MIE en ambos diseños y el grupo de control (N = 45, M = 13, F = 32) estuvo expuesto al método de lectura tradicional en el diseño uno. Con base en la evidencia que fue principalmente cuantitativa y en parte cualitativa y los análisis que también se realizaron por separado en ambas partes de los datos, se respondieron tres preguntas de investigación y, en consecuencia, se probaron tres hipótesis de investigación por separado en el diseño uno y el diseño dos. El resultado en el diseño uno mostró que hubo una diferencia de medias estadísticamente significativa (M.D = 4,81) con un tamaño de efecto medio d = 0,73 a favor de MIE. El ANOVA y la prueba t independiente mostraron que MIE favorecía a los estudiantes masculinos (con M = 17.8) que a las estudiantes femeninas (con M = 6.3) con $p = 0.002 < 0.05$. El coeficiente de correlación de Pearson (r = -0,256, p = 0,158 > 0,05) entre las puntuaciones de la prueba de rendimiento y la evaluación no mostró una correlación significativa. El resultado en el diseño dos mostró que había una diferencia de medias estadísticamente significativa (M.D = 2,65) con un tamaño del efecto grande d = 0,99. El ANOVA y la prueba independiente mostraron que MIE mejoró la puntuación media de los estudiantes masculinos y femeninos sin diferencias significativas, como se evidencia en $p = 0.1 > 0.05$. Hubo una correlación significativa entre las puntuaciones posteriores a la prueba del rendimiento de la experimentación y las puntuaciones de los informes de laboratorio a medida que uno aumentaba y el otro también aumentaba (r = 0,531, p = 0,028 < 0,05). Los datos cualitativos del cuestionario y la entrevista de estudiantes y profesores concuerdan con los hallazgos principalmente de los datos cuantitativos, excepto en un caso en el diseño uno.

Palabras clave: compromiso interactivo basado en modelos, método de lectura, modelos básicos, representaciones múltiples.

I. INTRODUCTION

Problem solving and experimentation are the most important cognitive skills [1]. They are central in Newtonian mechanics and physics. Currently the main focus of research attention are said to be a shift from a novice problem solver to an expert problem solver/a physicist [2], and student competence in interpreting and using different representations, and in coordinating multiple representations such as a graph, picture, free-body diagram, formula etc. [3].

It is evident that what hinders student's competence in problem solving and experimentation mainly depends on student's prior knowledge [4, 5]. Due to alternative conceptions students make unsuccessful association with physics concepts that hinders their problem solving and experimentation ability. It worthy to mention research works of scholars[6, 7, 8] who reported that the contribution of model based instruction is the integration of cognitive and social context. We need process-oriented instruction that encompasses both internal and external processes to a given student who is engaged in problem solving and experimentation activities.

The work of Zou [9] published in American institute of physics, AIP conference on using students' design tasks to develop scientific abilities. A preliminary study has shown that, probed by a performance-based task, the identified scientific abilities are more explicitly demonstrated by design-lab students than non-design lab students. Moreover, French and Cummings [10] have reported at physics education research(PER) conference on the effectiveness of abridged interactive lecture demonstration(ILD). He obtained an obvious advantage of using a shortened form of the standard ILD protocol which brings a significant reduction in the time necessary to perform the demonstration series.

The current study focuses on model-based interactive engagement that was employed in teaching Newtonian mechanics course along with distinct stage –by- stage cyclic learning episodes as shown in Fig. 1.

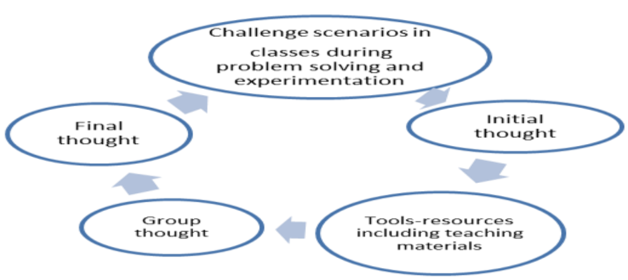

FIGURE 1. Stage-by-stage episodes of model-based interactive engagement and each arrow corresponds with assessment and feedback (adopted and modified from Al-arfaj [11]).

Stage 1. Challenging scenario focuses on topics about fundamental principles in mechanics.
Stage 2. Initial thought focuses on abstraction/idealization of real world in model building during problem solving and experimentation. The process consists of creating models in different forms such as (i) conceptual (ii) assumption based propositions (includes estimate quantities and make assumptions and approximations) (iii) graphical (v) mathematical
Stage 3. Tools (computer modeling), resources and teaching materials help to realize creating models in different forms such as (i) conceptual (ii) propositions (iii) mathematical (v) graphical representations.
Stage 4. Group thought focuses on generating hypothesis and generalizations. This process consists of model building with multiple representations in a small group discussion.
Stage 5. Final thought focuses on using models to construct meaning. The process consists of reflection and evaluation to make concrete the explanation and prediction made about real physical phenomena in the system and checking for connections, revising hypotheses, and generalizations.

In this regard the effective classroom practices as documented in a set of modules issued by [12] regional workshop on teaching and learning in higher education at Moi University are (i) encourage discussion, interaction and involvement (ii) encourage participation (iii) give feedback early and often times (iv) use assessment techniques like continuous assessment, self-assessment and peer assessment (v) create a small-class atmosphere in a large-class setting.

In Ethiopian context, the guiding principles of curriculum planning and design as documented in Institute of Curriculum Development and Educational Research [12] are (a) to connect theoretical knowledge with practical real life situations; and (b) to use problem solving approach.

A. Statement of the problem

Several researches indicated that a shift to student-centered classrooms helps a lot for students to learn by doing. In this regard my experience leads me to ask: is active learning valued in the physics department at my home University and can model-based interactive engagement fill that gap?

My experience again leads me to ponder: are the existing practices encouraging reproductive approaches rather than deep approaches? Empirical evidence [13, 14] indicated students rarely express their conceptual knowledge explicitly in problem solving and experimentation activities performed in teacher-dominated approach characterized by presentation of facts and skills, with the assumption of that students will see the underlying structures in the content. They (i) systematically ignore the point of what we tell them (ii) do not have the same schema associated with the ideas/words that we have.

B. Research questions

Research question 1:- Do EG students score statistically significant performance test results in problem solving and experimentation in mechanics when taught by MIE as compare to CG students taught by TI?
Research question 2:- Will MIE bring statistically significant results in performance test for female students in problem solving and experimentation in mechanics course better than other students?

Research question 3:- Do formative assessment and feedback determine students' performance during problem solving and experimentation in selected topics in mechanics?

C. Purpose of the study

The main purpose of this study is to examine the effect of Model-based Interactive Engagement (MIE), a teaching method that is mainly characterized as interactive engagement of small group of students when doing multiple representations based on basic models, on problem solving and experimentation abilities in learning Newtonian mechanics course.

D. Significance of the study

This study has importance in the preparation of curriculum materials and instructional design. It is significant in helping teachers and curriculum developers to address and design teaching and learning processes.

E. Scope of the study

The problem solving and experimentation activities in this study are up to the standard of the course but are purposely tuned to match with MIE. The MIE is mostly about basic models and their multiple representations in mechanics. The basic models in Newtonian mechanics are foundational for the advanced courses in the undergraduate physics curriculum. The attention given to basic models in the course makes MIE different from traditional lecture methods.

II. METHODOLOGY

A. Procedures

The study was conducted in physics department of Arba Minch University using seventy nine first year physics and chemistry students. According to the curriculum, mechanics course (Phys1011) and experimental physics-I (Phys1012) are offered in the first semester for physics students and mechanics and heat (Phys1241) is offered in the first semester for chemistry students.

The list of topics of mechanics course for physics students and the same for chemistry students except heat and temperature instead of fluid mechanics

- Vectors
- One dimensional and two dimensional motion
- Particle dynamics
- Work and energy
- Impulse and momentum
- Rotation of rigid bodies
- Gravitation
- Simple harmonic motion
- Fluid mechanics

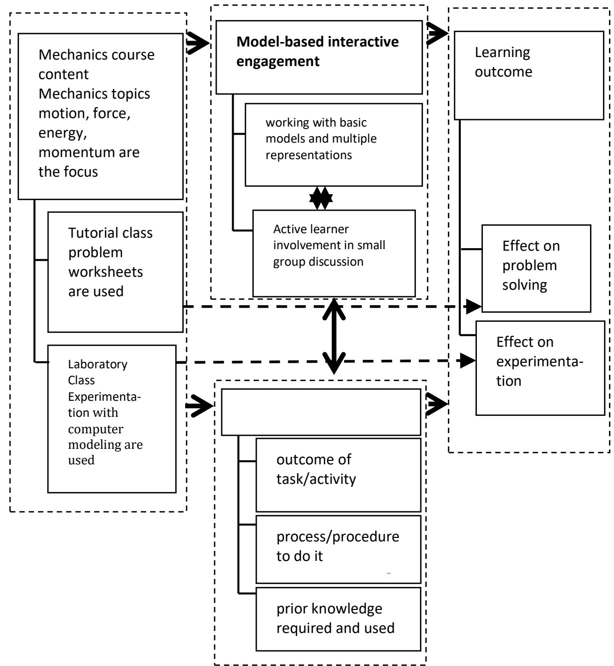

FIGURE 2. Conceptual framework.

The function of each part of the conceptual framework arises from the curriculum itself but more integration and organization of the parts is sought in this study. The sequence of chapters goes first with motion and followed by force, energy, momentum and extra that shows the learning progression in mechanic course. The real world situation is directly or indirectly the subject of problem solving and experimentation. The instants and events that students encountered in problem solving and experimentation are reflections of the real world situation. The projections of the real world in topics like motion, force, energy, and momentum within mechanics is possible with the help of basic models. Basic models can be expressed and defined with multiple representations such as scale models (show spatial relationships), conceptual models (symbolic representation with underlying structures), analogue models (a physical system as a model for another) and extra. They can be presented in a very simple way by emphasizing only on essential elements so that they conserve their explanatory power. Formative assessment and feedback help both teachers and students monitor progress as a consequence of which formative feedback will be given by a teacher or peers as support and remedial measure on the identified errors and mistakes committed as well as misconceptions will be subjected to more clarification and explanation. The active involvement of the learner should be encouraged through questions and answers until the learner is able to do activities by her/himself.

In mechanics we can deal with real objects which can be simplified and idealized by selecting important attributes and analogies. These simplified and idealized representations are known as conceptual models.

We can list some conceptual models in kinematics with the corresponding dynamic models having a function as descriptive model (representing change by explicit functions of time) and casual model (specifying change by differential equations with interaction laws) respectively. The dynamic models are suitably used in computer simulations.

Table I. Basic models in mechanics (Adopted and modified from Hestenes, [15]).

Kinematic models		Dynamics models	
Conceptual	Mathematical	Conceptual	Mathematical
1. uniform motion with constant velocity	V = constant a = 0	Motion with no force (e.g free particle)	$\sum \vec{F}_i = 0$
2. Uniformly accelerated motion with constant acceleration	V = Variable a = constant	Constant force	$\sum \vec{F}_i = constant$
3. Simple harmonic Oscillator (SHO)	$a = -\omega^2 x$	Motion under restoring force	$\sum \vec{F} = -k\vec{x}$
4. Uniform circular motion (UCM)	$a_{rad} = \frac{v^2}{r}$	Motion under central force	$\sum \vec{F} = m\vec{a}$
5. Isolated system	E = constant (total energy is conserved)	Absence of external force	$\sum \vec{F}_{external} = 0$

In addition let us see the excerpt of the record of small group of students that were engaged to solve the following question.

We describe constant acceleration motion with the variables and parameters v_{xi}, v_{xf} , a_x, t and x_f - x_i. Of the equations in the book, the first does not involve x_f - x_i. The second does not contain a_x; the third omits v_{xf} and the last leaves out t. Therefore, to complete the set there should be an equation *not* involving v_{xi}. They instructed to derive.

The record of small group of students who were engaged to solve the given question was transcribed in such a way that at first they searched the set of equations somewhere in the textbook and then tried to solve the problem. Finally, they came to understand the problem and obtained additional equation not involving v_{xi}.

$$x_f - x_i = v_f - \frac{1}{2}at^2 . \qquad (1)$$

This new equation was found important to solve the previous question students were in charge in a simple way. To consolidate the knowledge they gained homework questions were assigned for the small groups of students to solve it in line with the problem solving strategy. The format guides them to follow steps of forward looking model based strategy. They were also told to make necessary preparation on projectile motion to be discussed in the next tutorial session.

Let us see the work of small group of students in measuring acceleration of motion along air-tracker where the manual and the built-in instruction described the procedure in detail.

Accordingly they collected the data in table form and the analysis was made to determine g (the acceleration due to gravity). The graph in fig. 5 was drawn with a slope = m = 1/2 a = 1/2 g sinθ. Students have used data analysis software in the software package to obtain the following graphs.

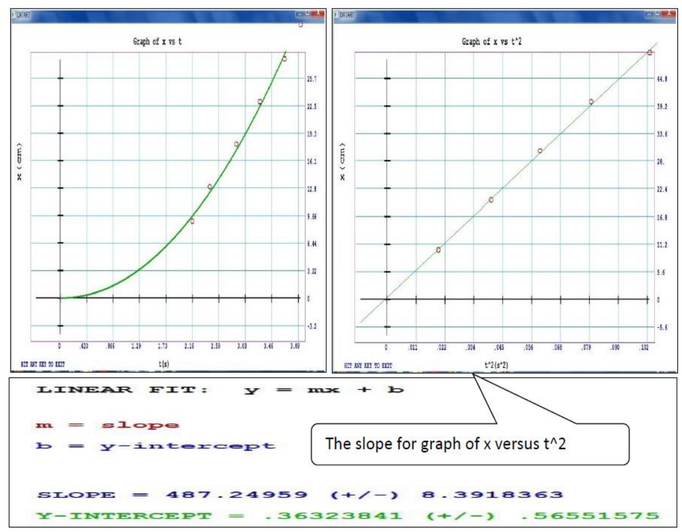

FIGURE 3. Example of graphs drawn by students that show x-t and x-t^2 graphs.

The software can easily calculate the slope of x vs t^2 graph and equated with 1/2 a = 1/2 g sinθ. The slope of the graph was calculated to be 487 cm/s^2 or is the same to say 9.74m/s2 = g sinθ that helped them to estimate the value of g. Students were also encouraged to use standardized lab reporting format in computer based experiments.

The conclusion of the lesson involved making remarks either from students or the instructor side in order to substantiate the outcomes of problem solving and experimentation activities. That was done in order to advance meaning making and meaningful learning, which could be ensured as students work to understand and apply scientific models. The computer modeling was designed in such a way that students were engaged interactively to think and reason out based on basic models. The truth is that not every model has to fit to every phenomenon but the controversy (discontent) that occurred has opened up opportunities for students to be able to build appropriate model for that specific phenomena. The final evaluation stage was meant verification of the correctness of stage by stage progressions in experimentation and problem solving which could be done in group discussions and oral presentations to be supported by assessment and feedback practices.

The result in fig. 4 is reported by small group of students who performed a simulation experiment shown in fig. 8 based on MIE as reported in the new lab report format.

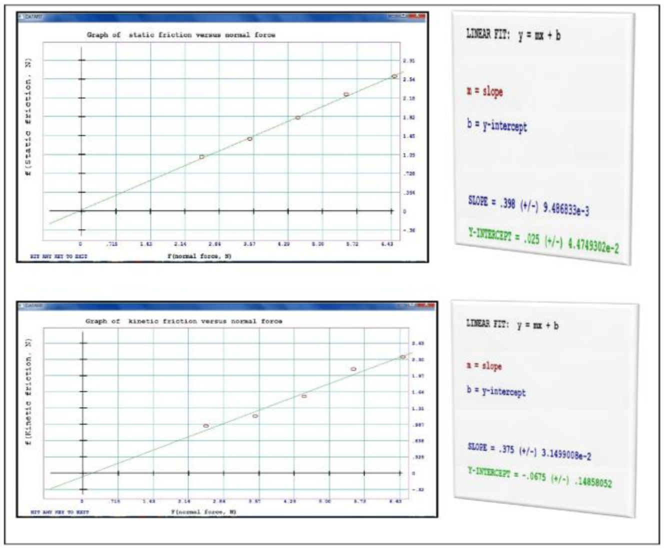

Figure 4. Calculated values for friction coefficients.

The following solution paper of a student was sampled from the students in experimental group during performance posttest.

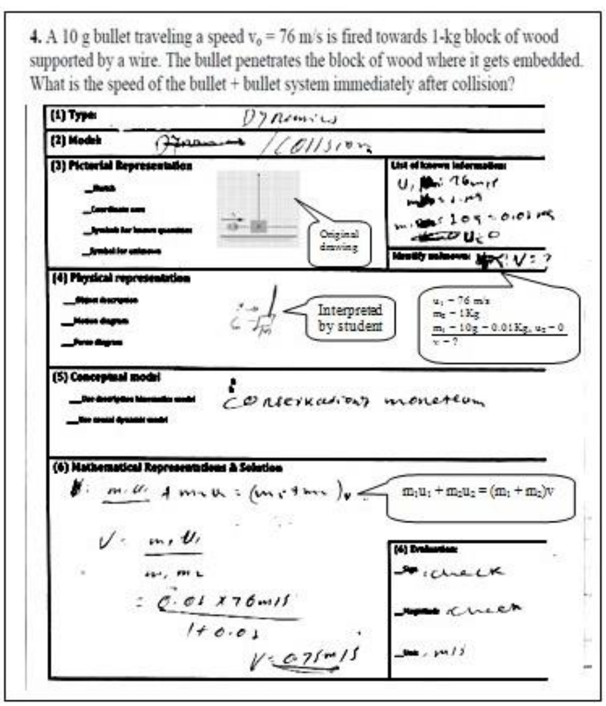

Figure 5. Examples of students work on performance posttest.

B. Instruments

Based on the calculation carried out by [16] Cronbach's Alpha of PSSS was found to be 0.82. The calculated values of Cronbach's Alpha for questionnaire used for experimentation ability was calculated as 0.899.

III. THE RESEARCH RESULTS

A. Main results of the analysis based on null hypothesis (H_{01})

H_{01}: there is no significant difference between the performance test mean scores before and after the study of (a) the EG and CG students of the design-one targeting problem solving ability and (b) within single group students in physical and simulation experiments of design-two targeting experimentation ability.

Table II. The result of independent t-test on the problem solving performance posttest scores.

Problem Solving Performance Posttest						
Group	N	M	SD	t	P	Effect size
EG	32	8.47	8.68	3.106*	0.003	0.73
CG	44	3.66	4.71			

(* means significant at .05 level; Standard deviation = SD; Mean = M, N = Total number).

The result given in Table II revealed that as it was predicted in the first research hypothesis for design-one, there was significance difference in scores for EG, M = 8.47, SD = 8.68 and CG, M = 3.66, SD = 4.71; t(74) = 3.106, p = 0.003< 0.05(two-tailed). The new teaching method (MIE) compared to the traditional lecture method can bring better scores in performance tests as applied to problem solving.

I found it is useful to compare the problem solving ability achieved based on PSSR

$$g = \frac{postscore\% - prescore\%}{100 - prescore\%}.$$

Accordingly MIE produces g = 0.27 and TI produces 0.007 based on Coletta & Phillips (2009) higher g are typically in the range 0.3 – 0.6.

Table III. Paired-samples t-test on experimentation performance posttest

	Lab practical work	N	M	SD	t	df	p	Effect size
Experimentation performance	Physical	17	13.76	2.5	-4.1*	32	.00	.99
	Simulation	17	16.41	.94				

The result given in Table III revealed that as it was predicted in the first research hypothesis for design-two, there was significance difference in scores in simulation experiments performed by MIE, M = 16.41, SD = 0.94 and physical experiments performed by conventional traditional method, M = 13.76, SD = 2.46; t(32) = -4.1, p = 0.00< 0.05(two-tailed). The new teaching method (MIE) compared to the conventional lecture method can bring better scores in performance tests as applied to experimentation.

The paired samples t-test was conducted on the scores of experimentation ability questionnaire (see table 13). There was significant improvement of students' score on the scale between pretest and posttest, t = 2.23, p = 0.033 < 0.05. The magnitude of the difference in the means (mean difference = 6.33) was medium (Cohen's d = 0.4).

Table IV. Experimentation ability questionnaire posttest and pretest comparisons.

Paired-samples t-test								
Experimentation ability scores	Pretest		Posttest		t	df	P	Effect
	M	SD	M	SD				
	42.	10.	48.	11.	2.2	2	.03	.4

B. Main results of the analysis based on null hypothesis (H_{02})

H_{02}: the mean score for female students in performance test is not better than other students before and after the study of (a) the EG and CG students of the design-one targeting problem solving ability and (b) within single group students in physical and simulation experiments of design-two targeting experimentation ability

The teaching method and gender as factors of the independent variable and the interaction between them were found to have statistically significant effect on the dependent variable known to be the problem solving performance posttest(at α = 0.05). The result of the ANOVA analysis indicated there was statistically significant main effect for teaching method, F(1,72) = 22.27, p< 0.05, indicating that the intervention was effective. The actual difference in mean scores between the groups was large (partial eta-squared = 0.236 = 23.6 % of the variability of the subjects' scores in the problem solving performance test can be accounted for teaching method). Thus MIE teaching method produced more learning gain (M = 8.47) than traditional lecture teaching method (M = 3.66). There was statistically significant main effect for gender, F(1,72) = 14.86, p< 0.05. The actual difference in mean scores between the gender groups was large (partial eta-squared = 0.171 = 17.1% of the variability of the subjects' scores in the problem solving performance can be accounted for gender). The interaction effect between method and gender was statistically significant, F(1,72) = 8.45, p< 0.05. The effect size was medium (partial eta-squared = 0.105). The third significant factor which is labeled "interaction" means that the effect of teaching method was not the same for female and male students. It is now possible to apply the independent t-test that revealed there was statistically significant difference between mean of performance test score for male students (M = 17.8) and female students (M = 6.3) in the MIE group, t = 3.39, df = 30, and p = 0.002 < 0.05.

In the same way for design-two, The result of the ANOVA analysis indicated a main effect of teaching method, F(1,30) = 10.89, p< 0.05 was statistically significant. Thus MIE teaching method produced more learning gain (M = 16.41) than traditional lecture method (M = 13.76). Partial η^2-eta squared was 0.266 (26.6 % of the variability of the subjects' scores in the experiment can be accounted for teaching method and considered large in magnitude). Gender was not main effect, F(1,30) = 0.00, p > 0.05 and the interaction effect also was not statistically significant, F(1, 30) = 0.02, p> 0.05. Therefore, there was no statistical significant difference by gender for experimentation ability because the work was done in small groups.

The paired samples t-test result in table V on the PSSS scores showed there was statistically significant improvement on the scores of PSSS scale for both female and male students of MIE group between pretest and posttest, t = 2.19, p = 0.03 < 0.05.

Table V. Comparison of pretest and posttest scores on PSSS for female and male students of the two groups.

Paired sample t-test								
		Pretest		Posttest		t	p	Effect
		M	SD	M	SD			
EG	F(N	97.3	24.9	112.6	20.8	2.34	.02	.5
	M(N	104.	29.8	128	20.1	2.19	.03	.83
CG	F(N=2	120.	21.4	120.4	26.9	.017	.99	.003
	M(N=	120.	15.3	125.4	17.2	.7	.51	.26

In the same way for design-two, there was no statistical significant mean difference by gender on scores of experimentation ability questionnaire measure based on separate independent *t*-tests at pretest $t = 0.023$, $p = 0.98 > 0.05$ and at posttest $t = 1.68$, $p = 0.1 > 0.05$.

C. Main results of the analysis based on null hypothesis (H_{03})

H_{03}: there is no relation between the performance tests scores with the formative assessment and feedback used in design-one targeting problem solving ability and in design-two targeting experimentation ability.

Table VI. Correlation coefficients between the posttest scores and formative assessment scores of problem solving and experimental activities.

	R	*p*-value
Correlations between posttest and problem solving activities	-0.256	0.156
Correlations between posttest and experimentation activities	0.531*	0.028

The problem solving activities were not frequently scored in tutorial classes and against what was predicted there was no significant correlation between scores of problem activities and posttest scores, $r = -0.256$ and $p = 0.156 < 0.05$. The problem solving activities were not always subjected to a timely formative assessment and feedback. There was statistically significant correlation between scores of experimentation performance test and scores of assessment of experimentation activities with $p = 0.028 < 0.05$. It means there is dependence of experimentation performance posttest scores on scores of the lab reports as one increased the other increased too.

The overall impact of the intervention as reported by both the students and the teacher and revealed by the questionnaires, interview, and checklist was positive since it was helpful for students learning.

IV. CONCLUSION

The concluding remarks about the advantage of model-based interactive engagement over that of traditional lecture type instruction based on evidences of the research are the following

- As it was proposed that model-based interactive engagement instruction proceeded by focusing on certain basic models of the course. In this method students in small groups were actively engaged through elaborating and visualizing problems and experimentation activities in terms of different representations (multiple representations). The work of students should be guided by assessment and feedback that was offered by the instructor. Based on the objective data, this study confirmed that MIE teaching method is practical and effective in bringing about better outcomes in problem solving and experimentation performances in mechanics course.
- Despite the expectations that female students could benefit more in MIE teaching method, this study has found male students achieved better than female students in problem solving even though no significant difference was observed in experimentation performance because small groups were taken as unit of analysis.
- Sustainable introduction of formative assessment practices in model based interactive engagement lesson was proposed in this study. The result of the study showed that there was indeed positive correlation between assessment scores and experimentation performance post-test score. The result of this study showed significant correlation between experimentation performance test scores and formative assessment score of experimentation activities even though no significant correlation was obtained between problem solving performance test scores and formative assessment score of problem solving activities due to the fact that there was shortage of providing sustained assessment and feedback practices.

The study has direct implication to the learning and teaching of Newtonian mechanics and indirectly to other physics courses. The teacher has to set activities which can engage students mentally to think, plan, and act. Scaffolding supports through providing teaching materials like model based problem solving and experimentation strategies, formats, tools like computer apps are important. Successful physics teaching method should address students' alternative conceptions. There is no one best strategy for all classroom situations thus future research should focus in order to test new effective teaching strategies.

REFERENCES

[1] Frederiksen, N., *Implications of cognitive theory for instruction in problem solving*, Review of Educational Research **54**, No. 1. (1984).

[2] Walsh, N. L., Haward, G. R., & Bowe, B., *Phenomenographic study of students' problem solving approaches in physics*, Physical Review Special Topic-Physics Education Research **3**, 020108(2007).

[3] Cock, D. M., *Representation use and strategy choice in physics problem solving*, Physical Review Special Topics-Physics Education Research **8**, 020117(2012).

[4] Heuvelen, A.V., *Learning to think like a physicist: A review of research-based instructional strategies*, Am. J. Phys. **59**, 10 (1991).

[5] Trumper, R., *The physics laboratory – A historical overview and feature perspectives*, (Science & Education, Kluwer Academic Publisher: Netherlands, **12**, 645 – 670 (2003).

[6] Ramirez A. M., Clement, J., & Núñez-Oviedo, C. M., *An Instructional Model Derived from Model Construction and Criticism Theory*, in Clement, J. J., & Rea-Ramirez, A.M, (Eds.), Model-based learning and Instruction in Science (Springer, 2008).

[7] Gobert, D. J. & Buckly, C. B., *Introduction to model-based teaching and learning in science education*, International Journal of Science Education **9**, 22 (2000).

[8] Dancy, M. & Henderson, C., *Framework for articulating instructional practices and conceptions*, Physical Review Special Topics-Physics Education Research **3**, 010103 (2007).

[9] Zou X., *Using students' design tasks to develop scientific abilities*, (American Institute of physics, AIP conference, California University, 2007).

[10] French T., & Cummings K., *Effectiveness of abridged interactive lecture demonstrations*, (Yale University, USA, 2002).

[11] Al-arfaj, M., *The five stage cyclic model: An Online Integrated Approach to Teaching Physics*, International Education Studies **4**, 3 (2011).

[12] UNESCO, *Prospects: the quarterly review of comparative education*, vol. **XXIV**, no. 3/4, 471–485, (2001).

[13] McDermott, L., *Students' conceptions and problem solving in mechanics*. An I.C.P.E. book. International commission on physics education, I.S.B.N. 0-9507510-3-0. (1998).

[14] McDermott, C. L. *Improving the teaching of science through discipline-based education research: An example from physics*, European Journal of Science and Mathematics Education **1**, 1 (2013).

[15] Hestenes, D., *Modeling methodology for physics teachers*, Proceedings of the international conference on undergraduate physics education, (College Park, USA, 1996).

[16] Selçuk, S. G., Çalişcan, S., & Erol, M., *The effects of physics instruction on physics achievement, problem solving performance and strategy use*, *Lat, Am. J. Phys. Educ.* **2**, 3 (2008).