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Improving Secondary School Physics Students' Computational Dexterity using the Means-End Analysis (MEA) Approach in Solving Problems in Projectile Motion

Aderonmu, T. S. B., Omeodu, M. D. & Opuende, A. F.

[1]University of Port Harcourt Demonstration Secondary School, University of Port Harcourt Rivers State
[2]Department of Science Education, Rivers State University, Port Harcourt.
[3]Kalabari National College, Buguma, Rivers State
tope4ec@yahoo.com

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Abstract

The study was aimed at improving secondary school Physics students' computational dexterity using the Means-End Analysis (MEA) in solving problems in projectile motion. Two research questions were raised and answered while two hypotheses were formulated and tested. Quasi-experimental design specifically, the pre-test, post-test experimental and control group method was adopted for the study. Using the purposive sampling technique, 93 SS2 Physics students were selected in public secondary schools in Port Harcourt Local Government Area, Rivers State. Data collecting instrument was Projectile Motion Performance Test with a reliability index of r = 0.78. Data obtained for the study were analyzed using mean and standard deviation while while Analysis of Covariance and Scheff's Post Hoc analysis was used to test the hypotheses at 0.05 level of significance. The findings of the study revealed that there was better improvement of students' computational dexterity when solving problems in projectile using the Means-End Analysis than the Conventional Instructional Method. This is also evident by the Ho_1, $F_{(1,90)} = 124.483$ *and* $p = 0.00 < \propto = 0.05$. *The study also indicated that male students improved in their computational dexterity in projectile motion than their female counterparts across both groups employed for the study, while* Ho_2 *showed that there is no significant difference between male and female students mean performance scores exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics* [$F_{(1,88)} = 0.035$ *and* $p = 0.851 > \propto = 0.05$]. *The study recommends that Physics teachers in secondary schools should adopt the Mean-End Analysis approach especially during teaching of topics that are mathematical (like projectile motion) so that students' computational dexterity will be improved.*

Key words: *Physics, Computational, Dexterity, Problem Solving, Projectile Motion*

Introduction

Physics is a branch of science that focuses on matter and energy as well as provide the basic application of Mathematics in the understanding of reality of the world. The effects of Physics cut across numerous academic fields such as engineering, medicine, agriculture, science and technology. Physics is one of the physical science subjects that plays an important role in the technological development and industrial revolution of any nation. The knowledge and scientific skill derived in the study of physics is of tremendous use in solving diverse problems of humanity and providing solution to natural and artificial problems in the world at large. Mathematics provides the fulcrum for the interpretation ideas in Physics.

There is no doubt that much of the progress made by man is possible due to the applications of mathematical operations the ensured better understanding of both physical and social phenomena. The earliest civilization of mankind came through mathematical manipulation. The pyramid of Egypt constructed several years ago still remains tourist attraction to date. The construction of the pyramids involved sound and intelligent mathematical calculation. The marriage between Physics and Mathematics to the evolution and development of the civilization and overall advancement of human world confirms their importance. Owing to their conceptual, numeral and symbolic nature, both Physics and Mathematics is more align to the scientific and technology facets of our world than to any other aspect. Kwarki et al (2018) explained that important skills required for the study of Physics is useful analysis and clear cognition. These skills ensure that students unravel complex task in Physics, but they cannot be applied if they are not specifically written firstly in their language and characters. Therefore, the language is mathematical language.

Thorough understanding of Physics concepts is reliant on the description, physical processes and fluency in the language of mathematics. While Obafemi and Ogunkunle (2013) opined that Physics as a science subject uses Mathematics as its official language in linking conceptual principles learnt in during instructional interaction to the outcome of experimental activities obtained in Physics laboratories, Aderonmu and Nte (2014) noted that most Physics tasks derive solutions when they are mathematically answered. The application of mathematics in solving Physics problems reduces the complexities and abstract nature of Physics. Similarly, Okey and Charles-Ogan (2015) asserted that mathematics provides the required “form and definiteness” to the properties of matter and energy while harnessing nature through quantitative interpretations of ideas and imaginations. As noted in the Free dictionary by Farlex (2022) that;

> “the study of the nature of physics using mathematical operations not only makes it possible to obtain the quantitative characteristics of physical phenomena and to compute with a given degree of accuracy the course of real processes, but also provides the possibility of gaining insight into the very nature of physical phenomena, revealing hidden laws and predicting new effects” (p.24).

Mathematics can be broadly grouped into the following branches, Arithmetic, Algebra, Geometry, Trigonometry and Analysis. National Research Council (2011) asserted that mathematics learning in the 21st century requires critical thinking, creativity, technological literacy and importantly, computational dexterity. Computational dexterity involves the selection and application of mathematical operations to calculate and provide solutions to mathematical problems. Computation dexterity entails the procedure of providing answers to a task through mathematical operation or logic. Despite the prevalence of modern technology, mathematical computational dexterity in solving Physics problems remains an integral part for students' academic success in the future. Math computation skills comprise what is most refer to as basic arithmetic of addition, subtraction, multiplication and division. Other mathematics computational skills required by Physics students to acquire in order to obtain solutions to Physics questions includes operation like substitution, elimination, expansion, factorization among others.

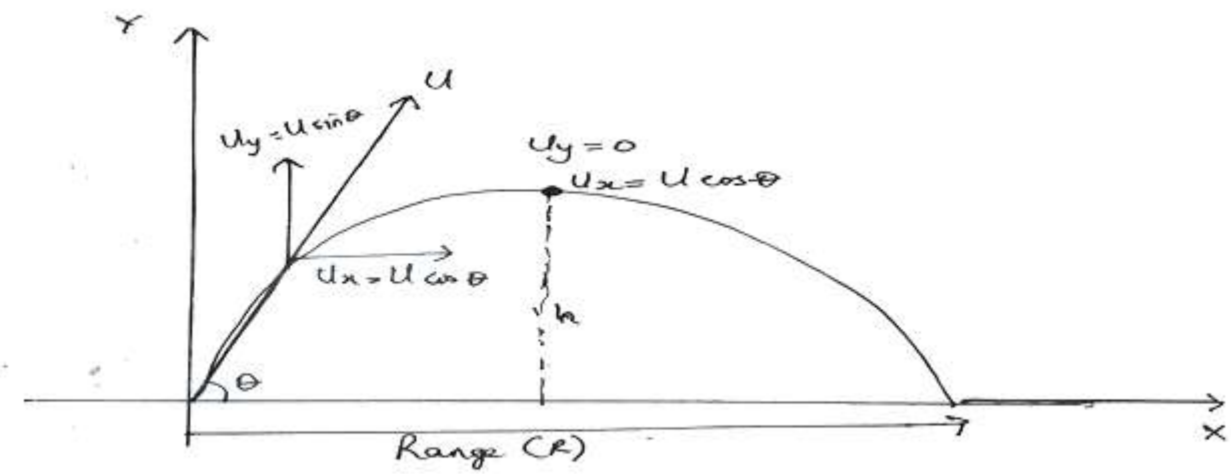
The ability to translate Physics problems that are mostly portrayed in the dimensions of everyday life task to numerical quantities and mathematically compute them to a logical conclusion place one at an advantage in navigating life issues. Where there exist deficiencies in students' ability to address Physics problems using appropriate computational procedure, invariably, students' are on the path of failure. Aderonmu and Nte (2014) classified the process of computational dexterity into;

i. Parameters identification and interpretation
ii. Application of associated formulae
iii. Substitution operation
iv. Numerical result
v. Extrapolation to physical conclusion.

Daniel et al (2020) explained that students' poor performance in Physics is either that the students lacks the appropriate mathematical computational dexterity required to solve physics problems or that the students do not know how to apply the computation process they have in physics to a specific problem situation. While Chassy and Jones (2019) revealed that more often than not the interrelatedness of mathematics and physics is not always emphasized in physics teaching, other studies have shown that Physics students that are poor in mathematics computation relatively perform poorly in Physics concepts (Aderonmu & Nte, 2014; Abdurarahman & Madugu, 2014; Awodun, Omotade & Adeniyi, 2013;). This implies that there is a strong correlation between students' mathematical background knowledge and their performance in Physics. The secondary school Physics curriculum consist of six important themes that are designed in attaining the dynamic nature of science and technology relevant to the need of the learners and the wellbeing of the society. These themes includes;

i. interaction of matter, space and time
ii. conservative principle
iii. wave motion without material transfer
iv. energy quantization and duality of matter and
v. Physics in technology.
vi. fields at rest and in motion

The topic "Projectile Motion" is among the topics in the theme "Interaction of matter, space and time" which is taught in the Senior Secondary two (SS 2) class. Study.com (2022) define projectile motion as a probable path traveled by a body that is influenced by the initial lunch velocity, the angle of lunch to the horizontal and the acceleration due to gravity. It is the motion of an object in the air that travels through a trajectory path that is parabolic. The object that moves in space is known as the projectile while the path taken by the object on flight is the trajectory. There are two important components of a projectile motion; the vertical component [U_y = U sinθ] and then horizontal component [Ux = cosθ]. The vertical component consist of



motion with constant acceleration due to gravity while the horizontal component has no acceleration.

Uy = vertical component
Ux = horizontal component
h = maximum height
θ = angle of inclination
U = initial lunch velocity

Research findings have shown that the topic "projectile" is among the difficult topics in the Physics curriculum (Bello, Opaleye and Olatunde, (2018); Obafemi and Onwioduokit (2013); Adolphus and Agbesor (2008). A topic is considered to be difficult according to Ivowi (1999) when it is difficult to teach as well as difficult to learn. There are various reasons why students may perceived the topic "projectile" as difficult. However, most students laments about the mathematical nature of the topic (Amusa, 2019) and their mathematical background (Semela, 2010). The West Africa Examination Council chief examiner report for Physics paper 2 in 2017 expressed that Physics students has poor mathematical presentation, inability to accurately state equations, formula and substitutions and evidently showed poor mathematical computational skills while attempting question on projectile motion. According to Reddish (1994) cited in Agommuoh (2020) stated that;

> Physics as a discipline requires learners to employ a variety of methods of understanding, the ability to use algebra and geometry and to go from the specific to the general and back which makes learning physics particularly difficult for many students. (p.59)

Consistent involvement in the activities of problem solving in Physics enhances students' academic performance. Problem solving is the core component of concepts of Physics that is cocooned with mathematics like projectile motion. Sathyanarayanan (2020) explained that problem solving is focused on the application of logic in an effort to attain the desired goal of a task from its problematic existing state cognitively by introspection, analysis, and experimentations. Problem solving poses as a powerful process in the understanding of projectile. Although, a number of factors as identified could act as impediments towards effective problem solving framework includes mental set, functional fixedness, stereotypes and negative transfer which is also peculiar to Physics learners, it is therefore exigent that a simplified, coherent and clarified problem solving approach is required importantly for task in projectile motion.

The Means-End Analysis (MEA) is a problem solving technique in which the solver (learner) identifies the major tripod components of the initiate problem state, the process of obstacle (sub-goals) elimination and the goal (solution). MEA is a variation of problem-based learning through a heuristic approach in the form of a series of questions as a guide to problem-solving (Raina, 2017).

Problem	Sub-goals to goal	Sub-goals to goal	Actions	Goal
Determine the total time of flight of a projectile projected with a initial velocity of 20m/s it an angle of 30^o to the horizontal. ($g=10m/s^2$)	Identification of parameters h, T, u, $\boldsymbol{\theta}$, g Recall of formula $T=\frac{2U\sin\theta}{g}$	Determine Sin $30^o = 0.500$ Substitute $T = \frac{2 \ X \ 20 \ X \ 0.500}{10}$	$T = (\frac{20}{10})$ s	T = 2s Total time of flight of the projectile.

Huda (2014) highlighted the problem solving procedure of the Means-End Analysis approach as follows;

i. presentation of problem using the heuristic based approach (by identifying relevant and required physical quantities).
ii. elaborate the conditions or requirements needed to achieve the ultimate goal (end state).
iii. the given problem is divided into sub-problems.
iv. identification of problem level based on sub-problems existing.
v. Problems are solved based on each sub-goals in order to achieve the ultimate goal (end state).

The idea behind the Means-End Analysis is fundamentally focused on the elimination of the sub-goals, which are defined as simpler level sub-goals consequently provides for the achievement of the end goal (solution). Huda (2014) stated that Means-End Analysis is a technique that splits the initial problem state and the end goal into different sub-goals which then proceed to perform various ways to reduce the difference between the problems and goals. The main stage of the Means-End Analysis is the identification of differences between the problem state and the goal state, the organization of the sub-goals, and the selection of solutions.

Aim and objectives of the study

The study was aimed at improving secondary school Physics students' computational dexterity using the Means-End Analysis (MEA) in solving problems in projectile motion. Specifically, the objectives are to;

1. determine the effects of Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics.
2. ascertain the effects of gender on students' computational dexterity in solving problems in projectile motion in Physics using Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM).

Research Questions

1. What are the effects of Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics?
2. What are the effects of gender on students' computational dexterity in solving problems in projectile motion in Physics using Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM)?

Hypotheses

Ho_1: There is no significant difference in the performance mean scores of students exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics.

Ho_2: There is no significant difference between male and female students mean performance scores exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics.

Methodology

The Quasi-experimental design specifically, the pre-test, post-test experimental and control group method. The research design consisted of both the experimental group (MEA) and the control group (CIM). The design is illustrated as shown below.

MEA	O_1	X_{MEA}	O_2
CIM	O_1	X_{CIM}	O_2

Where

O_1 = Pretest
O_2 = Posttest
X_{MEA} = Treatment for MEA group
X_{CIM} = Treatment for CIM group
MEA = Means-End Analysis approach
CIM = Conventional Instructional Method

The population of students used for the study consisted of all Senior Secondary two (SS2) Physics students in all public secondary schools in Port Harcourt Local Government Area of Rivers State. A total of ninety-three (93) SS2 students were used for the study which consisted of 61 male students and 32 female students. Students employed for both groups were in their intact classes with MEA group having 45 students (31 male students and 14 female students) and CIM group had 48 students (30 male students and 18 female students). The sample size was obtained using the purposive sampling technique in which certain criteria were stipulated that ensure the selection of the schools and students used.

The instrument used for data collection was Projectile Motion Performance Test (PMOT). The instrument was developed by the researchers and comprise of 20 open ended structured test items that basically focused on solving problems on determination of both horizontal and vertical components of a projected object, initial velocity of projection (u), time to attain maximum height (t), total of time of flight (T), maximum height attained (H), range (R) and angle of projection (θ) among others. Each of the question was scored a total of 5 marks based on the problem solving procedure employed. Therefore, the total score for PMPT was 100 marks which was equivalent to 100%. The instrument was validated by four experts and two experienced Physics teachers for face validity. A table of specification was developed for PMPT to ensure content validity. The instrument was also subjected to reliability test to determine the internal consistency using thirty-five (35) SS2 Physics students who were not part of the study. The scores obtained were analyzed using the Kuder-Richardson 21 (KR-21) and a reliability index of 0.78 was obtained making the instrument 78% reliable for the study.

PMPT was administered to the students of the MEA group and CIM group to determine their baseline knowledge which provided the pretest scores. This was followed by the treatment stage in which the MEA group were taught the topic "Projectile Motion" using the Means-End Analysis approach to solve mathematical problems associated with the topic. While the Conventional Instructional Method utilized the chalk-board problem solving approach to solve problems on projectile motion. The treatment for both groups took 2 weeks (240 minutes) of 120 minutes (40 minutes per period for each week).

The data obtained for the research questions were analyzed using descriptive statistics of mean and standard deviation while the hypotheses were tested using Analysis of Covariant (ANCOVA) at 0.05 level of significance.

Results

Research Question 1: What are the effects of Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics?

Table 1: Mean and standard deviation performance score of MEA and CIM groups

Groups	N	Pretest Mean	SD	Posttest Mean	SD	Mean gain
MEA	45	20.90	3.53	76.04	7.38	55.14
CIM	48	20.31	4.20	59.83	6.53	39.52

Source: Researchers' Fieldwork, 2022.

The result in Table 1 shows the mean and standard deviation performance score of students taught the projectile motion using problem solving approach of Means-Ends Analysis (MEA) and Conventional Instructional Method (CIM). The result disclosed that there was significant improvement in students' computational dexterity between both groups. Physics students that were in the MEA group had a mean gain score of 55.14 while those that were in the CIM group had a mean gain of 39.52. The findings of the study revealed that there was better improvement of students' computational dexterity when solving problems in projectile using the MEA than CIM.

Ho_1: There is no significant difference in the performance mean scores of students exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics.

Table 2: ANCOVA analysis of mean performance score of students in MEA and CIM groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6191.415[a]	2	3095.707	64.570	.000	.589
Intercept	12378.955	1	12378.955	258.199	.000	.742
Pretest	87.670	1	87.670	1.829	.180	.020
Groups	5968.140	1	5968.140	**124.483**	.000	**.780**
Error	4314.908	90	47.943			
Total	436468.000	93				
Corrected Total	10506.323	92				

a. R Squared = .589 (Adjusted R Squared = .580)

Table 2 revealed the ANCOVA analysis of students' mean performance score in projectile motion based on the instructional approach used for problem solving. It was indicated that there was a significance difference between the mean performance score of students exposed to MEA and CIM in projectile motion [$F_{(1,90)} = 124.483$ and $p = 0.00 < \propto = 0.05$]. The null hypothesis one was therefore rejected indicating that there is a significant difference in the performance mean scores of students exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics. The effect size for the treatment (groups) is medium (partial eta square $\eta^2 = 0.78$). Consequently, the direction of the significant difference found between the mean performances score of students in both groups was determined using Scheffe's post hoc comparison.

Table 3: Post hoc analysis of students' mean performance scores in projectile motion based on the groups.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
MEA	CIM	16.071*	1.440	.000	13.210	18.933
CIM	MEA	-16.071*	1.440	.000	-18.933	-13.210

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Analysis shown in Table 3 reveals the Scheffe's Post-Hoc comparison of mean difference at a probability level of $p<0.05$. It was indicated that the MEA group contributed most to the significant difference and as such was the most effective improving students' computational dexterity in solving problems in projectile motion in Physics.

Research Question 2: What are the effects of gender on students' computational dexterity in solving problems in projectile motion in Physics using Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM)?

Table 4: Mean and standard deviation performance score of male and female students in MEA and CIM groups

Treatment	Gender	n	Pretest Mean	SD	Posttest Mean	SD	Mean gain
MEA	Male	31	21.39	3.56	78.71	6.54	57.32
	Female	14	19.71	3.34	70.14	5.59	50.43
CIM	Male	30	21.17	3.76	62.87	6.55	41.70
	Female	18	18.89	4.60	54.78	1.22	35.89

Source: Researchers' Fieldwork, 2022.

Table 4 showed the mean and standard deviation performance score of students taught projectile motion based on the groups and gender. It was revealed that male students in the MEA group improved in their computational dexterity in projectile motion than their female counterparts as indicated by the mean gain [male = 57.32 and female = 50.43]. Consequently, male students in the CIM group had a mean gain of 41.70 as compared to their female counterparts of mean 35.89. The study therefore revealed that male students improved in their computational dexterity in projectile motion than their female counterparts across both groups employed for the study.

Ho_2: There is no significant difference between male and female students mean performance scores exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics.

Table 5: ANCOVA analysis of students' mean performance scores based on groups and gender.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7547.647[a]	4	1886.912	56.122	.000	.718
Intercept	13431.501	1	13431.501	399.494	.000	.819
Pretest	.004	1	.004	.000	.991	.000
Groups	5034.777	1	5034.777	149.750	.000	.630
Gender	1354.513	1	1354.513	40.287	.000	.314
Groups * Gender	1.190	1	1.190	**.035**	.851	**.010**
Error	2958.675	88	33.621			
Total	436468.000	93				
Corrected Total	10506.323	92				

a. R Squared = .718 (Adjusted R Squared = .706)

The ANCOVA data presented in Table 5 shows the interaction between groups and gender. Based on the analysis of $F_{(1,88)} = 0.035$ and $p = 0.851 > \propto = 0.05$], the null hypothesis two is therefore retained which implies that there is no significant difference between male and female students mean performance scores exposed to Means-End Analysis (MEA) approach and Conventional Instructional Method (CIM) in improving students' computational dexterity in solving problems in projectile motion in Physics. The effect size as indicated by partial eta square $\eta^2 = 0.010$ is small.

Discussion of Findings

Most Physics problems are Mathematics related problems which usually consist of an initial state, goal state problem solving operators and end result. In order to solve problems in Physics, students' capability to enhance their computational dexterity is quite essential. The findings of the study revealed that there was better improvement of students' computational dexterity when solving problems in projectile using the MEA than CIM. Collaborating with the findings of this study is the result of Arif et al (2019) where it was concluded that the Means Ends Analysis (MEA) learning model can improve reasoning skills with high N-Gain on the reasoning skills of planes. It was further noted that the practical implication of the Means Ends Analysis (MEA) learning model can be used to improving reasoning skills for students. Also supported by Yudi, Sariyatun and Hermanu (2017), they observed that the implementation of learning model of Means Ends Analysis can improve the ability of high-order thinking of students in Problem Solving learning. This is supported by the achievement of all indicators in analyzing and as well as evaluating. Yoradyastuti (2019) carried out a study to determine the effect of the Means Ends Analysis (MEA) Model on Mathematics Learning Outcomes in fifth-grade students and revealed that the Means Ends Analysis learning model can affect student learning outcomes better than the Conventional Learning Model. Zainal (2019) also studied the effectiveness of Means-Ends Analysis (MEA) Learning Model application on improving mathematical learning result of elementary school students. The result obtained was in line with the outcome of the study as it was shown that student mathematical learning before and after use of the Means-Ends Analysis (MEA) had a rise where the common pretest value was 42.50 then improved to the post-test value to 80.33 as compared to the conventional method with a pretest value of 43.87 and a posttest value of 77.41. The study therefore concluded that mathematics learning using the Mean-End Analysis in the experimental class had a higher improved problem solving ability as opposed to the conventional method of the control class. The study also indicated that male students improved in their computational dexterity in projectile motion than their female across both groups employed for the study. Several research outcome have also revealed the male students perform better than female students in Physics concepts that is cocooned with mathematics (Adolphus, Alamina & Aderonmu (2013); Obafemi, & Onwioduokit, (2013). Factors have been attributed to this disturbing state as Ganley (2018) noted that female students tend to have less positive attitude, lower confidence level and higher anxiety when it comes to concepts that is mathematical like "Projectile Motion". As evidence has shown that math anxiety is negatively related to performance, leading to avoidance and diminishing working memory resources needed to deal with mathematical tasks (Ramirez et al, 2016).

Conclusion

Means-Ends Analysis is a learning model of variation between problem-solving models and arrangement that presents material on heuristic-based solutions, elaborates into simpler sub-issues, identifies differences, and constructs sub-issues so connectivity occurs. The study was designed to investigate secondary school Physics students' improvement of computational dexterity using the Means-End Analysis (MEA) approach in solving problems in projectile motion. It was evident that from the study that students had better improvement in there computational dexterity when solving problems in projectile using the Means-End Analysis.

Recommendation

Sequel to the findings of this study, the following recommendations are posited.

1. Physics teachers in secondary schools should adopt the Mean-End Analysis approach especially during teaching of topics that is mathematical (like projectile motion) so that students' computational dexterity will be improved.
2. Physics teachers should encourage active participation of female Physics students during the teaching and learning of topics that is mathematical in Physics in order to ensure the improvement of their computational dexterity in solving problems.

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