International Journal of Education Humanities and Social Science

ISSN: 2582-0745
Vol. 4, No. 01; 2021

COMPUTER PROGRAMMING PEDAGOGY FOR ENHANCING LEARNERS' PROBLEM SOLVING SKILLS IN MATHEMATICS LEARNING

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ABSTRACT

Today's learners and teachers have to shift from being programmed by computers to programming computers. This study explored Computer Programming as depicting pedagogy for mathematical concepts in the varied Zones of Proximal Development. It presents effects of knowledge of Computer Programming on grade 10 learners' mathematical skills. The study sample comprised 20 learners divided equally into two groups. A pre-test and a post-test employed to both the experimental and control group to ascertain if they were comparable. Thereafter, a sequential case study research design was used comprising two tests, a questionnaire and an interview schedule respectively to determine the statistical significant relationship between the grade 10 learners' knowledge of Computer programming and their problem solving skills in Mathematics. Results show a 3.4% improvement in performance of the experimental group. Assessment from the questionnaire found that 79.98 % of experimental group learners showed positive attitude towards learning Mathematics through Computer Programming. The interview affirmed Computer Programming as a learning tool.

Key Words: Algorithms, Computer Programming, Mathematics, Problem solving .

1. INTRODUCTION

Integration of Computer Assisted Instruction (CAI) in mathematics pedagogy, which relies on general purpose educational tools, is more dominant than Computer Programming (CP) which focuses on execution of solutions by a Computer (Aydin, 2005). Ochanda J.P. and Indoshi (2011) say the former reduces drudgery of arithmetic, algebra and manipulations but hamper computational thinking. Berger (2005) and Gibson (2012) support a paradigm shift from CAI to CP. Mahoney (1988, p. 6) pointed out that "between the Mathematics that makes the device theoretically possible and the electronics that makes it practically feasible lies the programming that makes it intellectually, economically and socially useful".

Nataliya, Anna and Nataliya (2013) coin teachers and learners aged between 10 to 40 years' digital natives. While their forefathers had very little of CP they cannot avoid computational thinking. This agrees with Saeli, Jochems and Perrenet (2012, p. 73) that "new generation students are surrounded by computer related instruments and will possibly do a job that has not been invented yet". They state that generations should be versatile with technology of computing.

There exist significant gaps in personnel with strong backgrounds in Science, Technology, Engineering and Mathematics (STEM) disciplines (Afonja, Sraku-Lartey, Oni, 2005). The Zambian revised curriculum of 2013 addressed that challenge by introducing CP as a topic in mathematics syllabi (www.ibe.unesco.org). A knowledge gap on CP's relevance among the teachers and learners has since emerged. One such importance is to employ active learning techniques (Conference Board Of The Mathematical Sciences, 2016, July, 15). These provide opportunities engaging learners in mathematical investigation, communication, and group problem-solving, but also feed backing their work from experts and peers, hence a positive learning effect. This supports blended learning as improving traditional methods of teaching and learning (Mukabeta et al , 2014).

Assessing Mathematics pedagogy in the Zone of Proximal Development (ZPD), Vyogstky (1987) and Vygotsky (1978) affirm concept formation as priority. This study focused on algorithms to a problem. An encounter with an object invokes a concept image laying premise for experiential knowledge that develops informally over time. These are procedures without attention to Mathematical meaning. To the contrary, structured thought develops during learning. Berger (2005) says it is dependent on mediated link to the object of reference. Structured thought is available for abstraction but fails to implant itself in understanding within a short time.

Mathematics Pedagogy and CP are faces of the same coin. While the former intertwines intuition amidst structured thought with structured thought for physically visible objects the latter links intuition of the solution to some syntax. That demands thinking surpass the level of a learner today but not far from what they can presently do as required in the ZPD.

The study determined the extent to which learners' attitude towards CP in Visual studio 2008 impact their problem solving skills in Mathematics.

2. METHODOLOGY

2.1 Research Design

To provide a coherent picture of a unique situation a sequential case study, allowing multiple data collection techniques, was done on 20 participants divided equally into experimental (E-group) and control (C-group) groups. Tests were written before and after lessons, which lasted for three weeks, on CP. Kothari (2004) explains the quantitative paradigm assuming a careful measurement of the objective reality in the world as causes determine effects while interpretivism view claims that understanding of the world develops subjectively from experiences, thus a complexity of views is relevant (Harwell, 2013 and Kothari, 2004). This concurs with Zeslessie (2007) who reported that exclusive reliance on one method may bias or distort the picture of what is being studied. Therefore, the more the methods contrast the greater the researchers' confidence and overcoming the problem of being bound by methods. The C-group was taught the CP concept for three weeks after the study. This agrees with Creswell

(2009)'s recommendation on the benefits of the treatment given to the E-group that it can be provided to the C-group after the experiment.

2.2. Population and Sampling

The participants were grade 10 pupils (G-10) from one secondary school. Those in Grade 8 and 9 were not robust enough to adequately write algorithms since syllabi coverage of CP was from up to G-10. Fully trained Mathematics students in Colleges and Universities would unlikely struggle with concept images in mathematics yet seeing a participant struggle with a task could help pinpoint essential understandings of a concept in their respective ZPD. The teaching centred on CP concept on some topics already learnt. These were integers, linear equations in one variable, statistics, indices and commercial arithmetic. The E-group was taught to write a program on the selected topics. This ran parallel to revisions of the same topics with the C-group. In order not to sabotage the C-group, it later received the lessons. A survey to measure participants' willingness, knowledge of writing Computer programs and ability to justify in mathematical terms their thinking was done in the course of the experiment to shortlist interviewees. This validated and verified the responses in the questionnaire. The interviews were conducted after the experiment to avoid influencing perceptions and beliefs of the participants.

2.3 Sample Size and Statistical Data Analysis Techniques

Data collected from the tests of the experiment was analysed using a Student's t-test method for independent groups to determine whether there was a significant difference between the mean scores of the groups. It was preferred because it is recommended for small samples whose size is less than 30 units (Montgomery, 1997). A Student's t-test for independent sample groups was given as

$$t = \frac{E^* - C^*}{\sqrt{\left(\frac{1}{n_E} + \frac{1}{n_C}\right)\frac{(n_E - 1){S_E}^2 + (n_C - 1){S_C}^2}{n_E + n_c - 2}}} \sim t_{(n_E + n_C - 2)}(\alpha = 5\%)$$

In the formula notation used was:

c* denoted the mean of the C-group ; E* denoted the mean of the E-group ; n_c for number of participants in the C-group ; n_E for number of participants in the E-group ; ${S_C}^2$ for variance of the C-group ; ${S_E}^2$ for variance of the E-group.

Other analyses were conducted using Microsoft Excel version 2010 and a Cronbach analysis from SPSS version 16.0.

2.4 Data Collection

The District Education Board Secretary (DEBS) for Chipili District and the Head teacher for the participating school approved the study by 14th November, 2016. The study was conducted from the 21st of November, 2016 to the 16th of December, 2016.

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Participants were given a pre-test and a post-test for group comparison purposes. The hypothesis claimed that the E-group would score higher than the C-one. It was analysed at 5% level of significance. The post-test assumed that the former would face little or no challenges in solving problems as compared to the latter.

The tests were marked using a standardized marking scheme where each question or part question was marked out of 100. Thereafter, an average score was obtained for each pupil. Next is a tabulation of the marking scheme:

Table 1: Marking Scheme of the Solutions from Learners in the Pre-Test and Post-Test items

Mark or Score in % per Problem	Observed Characteristics in the solution
0%	[No Input data/processing operation/decision realized] No attempt Problem recopied: - no understanding of problem evidenced Incorrect answer and no work shown
35%	[input data, symbol identified] Inappropriate strategy started: - problem not finished, left half way Approach unsuccessful: - different approach not tried Attempt failed to reach output
55%	[input data /well noted] Inappropriate strategy: - but showed some understanding of the problem Appropriate strategy used: - did not find the solution, or reach a goal but did not finish the problem Correct output and no work shown
65%	[Well-ordered steps] Appropriate strategy but Ignored a condition in the problem Incorrect answer for no apparent reason Thinking process unclear
75%	[unambiguous steps] Appropriate strategy or strategies Work reflects understanding of the problem Incorrect answer due to a copying or wrong processing (error)
100%	[A reasonable program] Work shown clearly and correct answer (appropriate solution process and correct answer)[ordered, unambiguous, clear steps and decisions]

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Constructing and representing algorithms using flow charts or pseudo codes measured the ability of a learner writing a Computer program during problem solving. A high level extent was emphasized by the ability to write an executable code in Visual studio 2008. The study asserted that pupils would be providing a varied range of algorithms to the same problems, a scenario that presented a broad spectrum of how learners understood concepts.

Other measures included interpreting and designing an approach to solving a given problem and ability of a pupil arguing out, with a colleague or teacher, their solution during a group discussion.

The questionnaire collected responses on frequency of learners' attitude towards CP during problem solving using a 10 item Likert Scale. The items were averaged to generate an overall response between Zero (lowest attitude) and 100 (highest attitude). Any score greater than 50 was classified as quiet high extent, else quiet low extent.

An interview on 4 of the E-group assessed their attitude towards CP in CAI for problem solving. This was based on designing solutions to some 7 item mathematics questions set from the selected topics. It extracted the qualitative aspect of the learner explaining and justifying their solution steps.

3. RESULTS

10 participants per group were enlisted for this study at the pre-test. The post-test had 7 participants for the E-group with 4 participants for the C-group because some of them pulled out towards the post-test in the study. It was observed that a reduction in the sample size during the post-test would affect the interpretation of the results when comparing the Pre-test to the Post-test ones in terms of uniformity of the source of results from participants. At the end of the study the E-group and C-group remained at 7 and 4 respectively. Thus the sample size of the Pre-test was also reduced to 4 and 7 respectively, following corresponding participants' results. The tables below report the obtained descriptive statistics for finding the T-value and its related *p*-value of the Student T-test.

Table 2: Descriptive Statistics for the Pre-test.

PRE-TEST RESULTS		
STATISTICS	**CONTROL GROUP (C_1)**	**EXPERIMENTAL GROUP (E_1)**
AVARAGE	56.66	55.91
VARIANCE	115.8	290.56
STANDARD	10.76	17.05

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DEVIATION		
SAMPLE SIZE	n_C=4	n_E=7

Table 3: Descriptive Statistics for the Post-test results

POST-TEST RESULTS		
STATISTICS	**CONTROL GROUP (C_2)**	**EXPERIMENTAL GROUP (E_2)**
AVAERAGE	36.67	41.05
VARIANCE	232.96	173.39
STANDARD DEVIATION	15.26	13.17
SAMPLE SIZE	n_C=4	n_E=7

The above statistics were used to find the T-values calculated for Pre-Test and the Post-Test in the case of unequal variances.

The difference in means of the pre-test was 0.75% while that of the post-test was 4.38%. The absolute difference between the mean differences was 3.6%.

The Pre-test hypothesis was dealt as follows;

Null Hypothesis, (H_0): There was no significant mean difference between the mode of thinking in the E-group and C-group.

Alternative Hypothesis, (H_A): There was significant mean difference between the mode of thinking in the E-group and C-group.

$T - value = 0.09$; Degrees of freedom = 9;$\alpha = 0.05$; p-value = 0.93; Since p-value > 0.05, we failed to reject the null hypothesis (H_0).

Based on the decision above we deduced that there was no significant mean difference between the mode of thinking in the E-group and C-group. Therefore, the two groups were comparable.

The post-test was dealt as follows

Null Hypothesis, (H_0): There would be no significant mean difference between the mode of thinking in the E-group and C-group.

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Alternative Hypothesis, (H_A): There would be significant mean difference between the mode of thinking in the E-group and C-group.

$T - value = 0.48$; Degrees of freedom = 9; $\alpha = 0.05$; p-value= 0.64. Since p-value > 0.05, we failed to reject the null hypothesis (H_0).

Based on the decision above that the null hypothesis was not rejected, it was said that there were no significant mean differences between the C-group and E-group after the learning of CP.

Insignificant though the mean differences were, there was a reduction in the p-value from the pre-test results to the post-test ones of the same participants. The pre-test recorded a marginal difference of 0.75% in the mean scores with the C-group performing slightly better than the E-group at 56.66% and 55.91% respectively. After the Post-test the E-group recorded a mean of 41.05% compared to that of the C- group which was 36.67%, giving a difference of 4.38%. Comparing the two differences of means between the Pre-test which gave 0.75% and that of the Post-Test which was 4.38%, it can be deduced that the E-group was consistent in performance while the C-group was not consistent. That accounted for the reduction in the p-value at post-test. The study attributed the consistence in performance of the E-group to the exposure to CP implying that the reduction of the p-value at the post-test provided some little evidence that CP could improve learners' performance. The increased margin difference of 3.6% in the two means from the Pre-test results to the Post-test ones indicated a possible potential of CP improving learners' problem solving skills in Mathematics, especially if the experiment was done following a paired comparison design. Even though T-test is suitable for sample sizes less than 30 those in the study were too small to provide sufficient conclusion on the differences between the means. Smaller samples fail to detect significant differences.

From the questionnaire the attitude of learners towards CP during problem solving was measured following responses from the 10 item Likert Scale. The questions were

Q12. CP is an interesting topic to learn practically. Explain your answer.

Q13. It is easy to work out a Mathematical problem once you know how computer programs are written down and executed.

Q14. Adopting programming technique makes it easy to interpret and approach any problem. Give any example to support your answer above.

Q15. Having learnt programming enables one to reach final solution to a problem easily.

Q16. The use of pseudo codes and flow charts in solving a problem enables one to get sufficient time to break down a problem into its smaller parts.

Q17. CP gives pupils an equal opportunity to work in groups.

Q18. CP gives pupils chance to argue out and justify their solutions in their working groups

Q19. CP gives pupils chance to argue out their ideas with their teacher

Q20. CP motivates a pupil to firstly work out his / her own problems before being assisted by peers allowing learners to interact mentally.

Q21. CP gives pupils chance to engage with solutions in real life problems.

The figure below shows the responses per question item:

Figure 2: Percent Comparisons on responses of attitude towards Computer Programming.

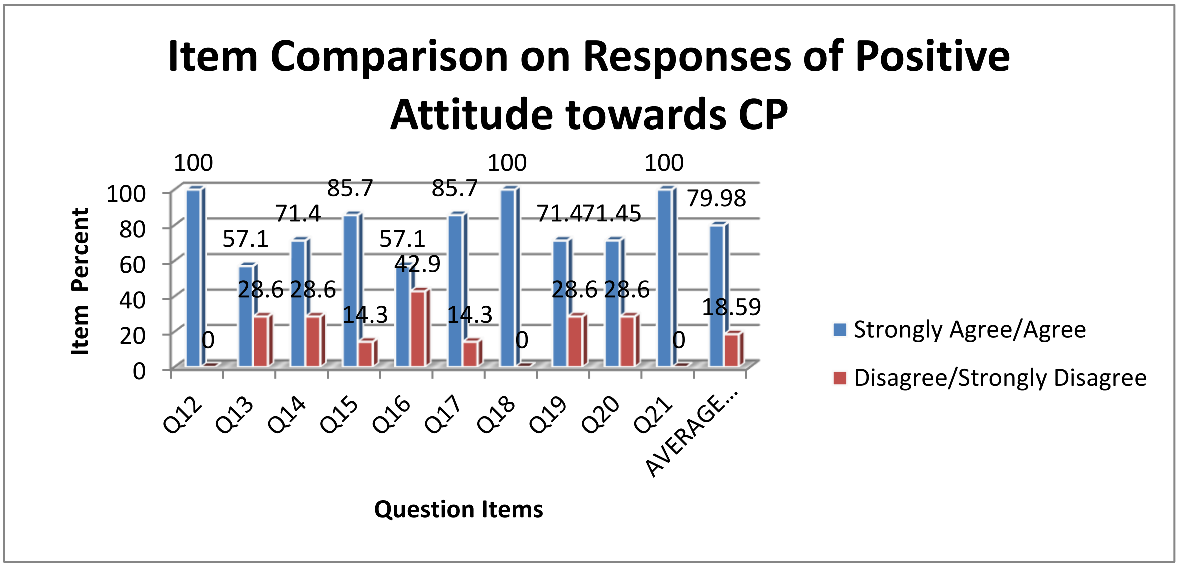

Figure 2: Percent Comparisons on responses of attitude towards Computer Programming

Figure 1 Using SPSS statistical software, Cronbach's alpha value was calculated to check on internal consistency of the subsection of the questionnaire as a measuring instrument for attitude towards CP.

Studies [12] recommend that a value of 0.7 or greater affirms that the set of questions were reliable. The Cronbach's alpha value was obtained as in the table below.

Table 4: Reliability Analysis

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q12	25.86	32.476	.553	.	.869

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Q13	26.86	21.143	.870	.	.839
Q14	26.29	36.238	-.187	.	.920
Q15	26.00	30.000	.738	.	.855
Q16	26.29	23.905	.906	.	.829
Q17	26.14	30.476	.374	.	.877
Q18	25.57	29.619	.876	.	.850
Q19	26.14	28.143	.872	.	.843
Q20	26.29	25.905	.846	.	.838
Q21	25.57	29.619	.876	.	.850
N of Cases = 7 ; N of Items = 10 ; Cronbach's alpha value = 0.872 (stdzd= 0.904)					

A reliability analysis was done on the perceived task values scale comprising 10 items. Cronbach's alpha showed the questionnaire to reach acceptable reliability of 0.872. Most items appeared to be worthy retaining, resulting in a decrease in the alpha if deleted. The one exception to this was question 14 which would increase the alpha to 0.920. As such, removal of this item should be considered. The observations on the section of the questionnaire item set showing homogeneity indicates that the instrument portrayed the required construct's validity. Interviews were recorded and transcribed.

4. DISCUSSION

The study established from the 0.75 mean differences that the two groups were comparable prior to the experiment with degrees of freedom = 9, t-value = 0.079 and T-critical = 1.833.

The post-test results showed a sharp increase of 4.38 in the mean difference. Though the two groups were still almost equal, there was an indication from the study findings that knowledge of CP could marginally improve the learners' problem solving skills in Mathematics tested at degrees of freedom = 9, T-value = 0.503, t-critical=1.833. This is in line with results of previous researches that report that learners develop thinking skills as they write their own programs (Papert, 1980). Activities such as coding and revision, design and debugging of computer programs accords them opportunities to develop higher mental thinking skills such as deductive reasoning and problem-solving (Papert, 1980).

Generally, performance of the C-group was not consistent compared to the E-group at Post-test. There was a difference of 3.6% in the means from the Pre-test to the Post-test. In the Post-test the E-group recorded a higher mean of 41.05 than the C-group which had 36.67.As learners laid

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solutions to the given Mathematical Problems following CP process they demonstrated some competence in understanding and interpreting questions. Nevertheless, they faced some difficulty of planning the course of solution before it was explicitly executed by the computer. That was ideal for group discussion among learners drawing their cognitive development from their differing ZPDs (Vyogstky, 1987) and (Vygotsky, 1978). CP allowed the teacher to pay attention to the respective ZPDs from the written programs. However, there was a common lapse on checking for errors in solutions. Such a situation could be corrected by scaffolding or mediation from others. Such group discussions carry a greater meaning since each participant displays their algorithm to solve a problem for the group. Their minds are engaged at the same time.

Assessment from the questionnaire, likert scale, found that learners were on average motivated by CP concept to an extent of 79.98 % showing quiet a high positive attitude. The interview on 4 participants of the E-group found out that learners interpreted CP as a tool that aided laying out a procedural solution to a problem. The interview questions were

(Q1.) How were you taught how to solve a problem in Mathematics?

(Q2.) What were your experiences in learning how to solve a problem without first programming?

(Q3.) What can you say about the importance of programming in learning to solve a problem in Mathematics?

(Q4.) What were your experiences in learning how to solve a problem after programming?

(Q5.)Use your calculator to evaluate (a) $(-3)^2$ (b) -3^2

(Q6.) Are the answers in (a) and (b) the same? Explain your answer in terms of the steps followed in working out each one of them in relation to computer programs.

(Q7.) Do you have anything else you would want to add to what has been discussed on CP?

Expressing their feelings during the interview session on question they pointed to such virtues as

a) CP helps to solve problems very fast

b) CP helps to generalize solutions for others to follow

c) CP helps to decompose a problem

The questionnaire established some difficulties faced by pupils while learning CP like understanding of the syntax of the programming environment and coding of algorithms. Such constraints resulted from little access to computers by the learners. Whilst they learnt how to write computer programs for their mental solutions to some problem practicing programming was restricted to the times of the learning sessions. In addition, due to low computer literacy pupils took time learning a computer as a machine instead of concretizing concepts of CP.

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The interview observed that learners insisted on CP allowing them to lay down a procedure to work out a problem. Unfortunately, they failed to completely clarify their feelings about it. The study found that learners were unsure with when to adopt skills of programming to solve a problem. They interpreted it as any other concept in Mathematics and so they would use it where they were instructed to do so. This was evident on some questions where solutions found did not result from any written down algorithm. Pupils solved in the usual way they did even before the experiment. Though they seemed to have read and understood the questions first they obtained varying solutions. This showed some development of problem solving skills of planning and evaluating one's solution. The study established that learners lacked the stable knowledge of CP. They rarely distinguished a computer from CP. This was evident in the response of the importance of CP on Mathematics problems. Answers alluded to pressing of keys as it is the case with CAI, calculators for example that are commonly used in Mathematics in secondary schools.

5. STUDY LIMITATIONS

The study was limited by unequal sample sizes between the two groups due to some participants withdrawing in due course at their own will, especially in the C-group. That made the sample size too small from the intended one. Additionally, the study was conducted at one secondary school which was purposely selected. The experiment in the study was conducted in 3 weeks and thus did not accord the participants the required time and experience and that could compromise the results.

6. CONCLUSION

The study found that knowledge of CP has a potential to improve the problem solving skills of learners in Mathematics if taught practically. It creates an equal enabling environment for the teacher to involve each learner actively in their ZPD. CP if handled practically changes the attitude of learners to laying logical solutions to problems in Mathematics. The process of coding formulae by learners themselves gave them confidence to relate intuition of concepts in Mathematics to their formal structures. It enforces active teaching and learning in Mathematics to take place from the known input data to the unknown output result of a problem. Every learner brings out their idea, correct or wrong, on any given problem. That takes group discussions among learners to higher mental interaction levels. CP encourages learners to validate each other's solution to a given problem in Mathematics.

7. STUDY IMPLICATIONS FOR THEORY AND PRACTICE

This study advocates for CP pedagogy for mathematical concepts considering that five topics from the Secondary School syllabus have been empirically tested and verified in this study that they can be inclined to CP pedagogy. This study observed that the topic of Computer was considered by learners as an entity separated from the other topics in the Mathematics syllabus. To this end, this study recommends that let CP be integrated at the end of each mathematical concept being taught.

To various schools in Zambia, it can be advised that learning of CP in Mathematics should move from theory to practical projects to ensure positive growth of rigorous thinking. Since the

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computer topic is taught from G-8 to G-10 that should instill computational thinking in learners as it accords a reasonable time frame for pupils to understand CP concept. It can be said that examination questions on CP can be randomized on any topic in the mathematics syllabi. This will trigger in teachers and learners of mathematics a paradigm of outlining logical programs for learners to comprehend, validate and apply in solving a given problem away from the tradition of just demonstrating the answers without any arguable technical handles forecasting the solution passage.

The study further recommends that Mathematics teaching methods should adapt to programming as it encourages mental interactions amongst learners in the course of designing programmes. Doing so will yield fruitful group discussions away from traditional groups of one solving for fellow learners while others just listen.

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