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Teaching within the Lens: The Use of Problem-Based Learning Strategy for Learner's Attainment of Critical Thinking Skills in Public Secondary Schools in Kenya

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Abstract: *The Problem-Based Learning Strategy (PBLS) is one of the most powerful instructional strategies on learning and achievement, but its impact can be determined arising from the behaviour of the learners who graduate after exposure to it. Its influence has been frequently mentioned in earlier research, surprisingly most educators have systematically and consistently not adapted to it, resulting to lower Learning outcomes from the learners. This study provides the use of PBLS for learner's attainment of critical thinking skills in public secondary schools in Kenya. The objectives of the study were to determine the extent to which instructors' use PBLS as a teaching strategy to promote problem solving abilities of girls in Physics and evaluate the gain in problem solving abilities of girls in "Fluid Flow" when using problem-based learning strategy. The study adopted constructivist theories of learning. Quasi-Experimental design was used with 4 girls' schools targeted in Bungoma County. The study sampled Form two students because the topic of fluid flow is taught at form two. Simple random sampling was used to assign schools to experimental and control groups. The study used motivation questionnaire, physics Achievement Test (PAT) and Observation schedule. Two groups of each n=40 either control or experimental were exposed to pretest and post-test. The reliability coefficient was calculated using KR-Fomulla-20 at 0.75. With the aid of SPSS 26.0, data was analysed using descriptive and inferential statistics and presented in form of tables. Although there was inadequate use of PBLS before the experiment, results show that all the variables were significant.Thus, the use of PBLS as a teaching strategy promotes learners' CTS at the study area. Similarly, the study found significant difference in the level of girls' problem-solving abilities towards Fluid Flow, a topic in physics between students who were exposed to PBLS and those taught using conventional methods. There is need for upskilling or retraining of teachers for the adoption and use of PBLS in schools. We recommend the method should be strongly advocated by policy makers, the Government, Principals and teachers while teaching science subjects. The study is important in bringing public sector reforms in the education sector especially with Competency Based Curriculum.*

Keywords: *Constructivists theory, Learner's Attainment, Problem-based learning strategy, Learner's Critical Thinking Skills*

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1. Introduction

There has been a shift on the emphasis of teaching science from the theoretical point of view to the exploratory, inductively, deductively and through experiments. For several decades, the aspect of teaching and learning has been very emotive to educationists and policy makers, yet they have not conclusively agreed to the best pedagogical strategy. One of the strategies proposed over time is the use of 'Problem Based Learning Strategy' (PBLS). It is one of the strategies envisaged among the early philosophers such as John Dewey, Jerome Bruner, Maria Montessori, and Edgar

Dale which have a bearing to social constructionist opinion on learning (Tan, Shen & Zhao, 2023).

In the PBLS approach, proficiency in practical skills, and not masterly of structures is the primary aim and places learners as stakeholders of knowledge creation unlike traditional models of teaching and learning where learners are passive consumers of information (Gul, Kanwal & Khan, 2020; Njoka, et al., 2021; Chang, Wu & Chang, 2023). Dewey, as a proponent of active learning process and hands on experience, contend that proper learning should be built around interaction and experience. In the same vein, PBL involves tackling of complex issues and problems, which relate to Dewey's thought of the role of education in everyday life. Bruner's theories emphasize the aspect of learning as a social process where learners engage actively. In comparison to PBLS, Bruner's idea of 'spiral curriculum' is seen in snowballing complexity. Similarly, Montessori emphasize the learner's capacity to build their learning practises. This school of thought is in line with PBLS that emphasize on self-directed learner activities, learners fully account for the learning development hence they are both child-centric, and self-directed (Njoka, et al., 2021). Quílez, 2021; Suh, et.al., 2023).

Edgar Dale was the US trainer who believed in actions that lead to substantial learning in what is known as 'Cone of Dale'. The cone has different parts with the base as most participatory and effective methods while the apex denotes abstract strategies being the least effective. Similar thoughts were recently illustrated by Upahi and Oyelekan, 2020; and Njoka, et al., 2021) that learners who do not, for instance, have hypothetical framework towards making-measurement, or tasks on how to evaluate, interpret, predict, observe and analyze what they do in experiment or practical work have a problem on how to construct data based on their potential and environment.

The more efficient way to learn lifelong skills in practical lessons is to place the learner as much as possible in the attitude of being a discoverer. The learner then brings in class the skill of imagination, curiosity and problem solving (Duch, et. al, 2001; Trott, Even & Frame, 2020; Meyer & Lima, 2023; Tan, et. al., 2023). One of the strategies often employed by teachers is the constructivists teaching strategies such as problem-based learning strategy (PBLS). PBLS is a firm philosophical and epistemological foundation and is founded on strong trajectory in diverse disciplines and especially in the science-oriented subjects. These psychological theories, like information processing theories, pinpoint the active involvement in promoting memory and remembrance. According to Borah (2021), teachers should use diverse motivational strategies to promote learners' learning process and develop their future life through academic performance (Suh, et. al., 2023).

Application of PBLS has been found to promote knowledge, inquiry and competences in behavioural, biological and social sciences (Njoka, et al., 2021). This model promotes learning outcomes by linking theory into practice. According to (Mang'eni, Waswa & Samikwo, 2023), the model is significant because it is student self-learning process, involve an array of critical skills, promotes teamwork in building communication, listening and interpersonal skills, enhances intrinsic motivation among the learners, and also promotes learning opportunities. PBLS is related to other similar strategies such as role plays, case studies and simulations.

In the recent past, Kenyan education has undergone metamorphosis of curriculum models from the 8.4.4 to CBC that has emerged with central focus on learner's skills and competences. This model mimics the PBLS that has been discussed for many years by the educationists and policy makers. Researchers have described PBLS as a method that bridges theory and practice, but there seems to be high variability in what the education stakeholders understand by this model, especially in teaching science-oriented subjects like physics (Trullàs, Blay, Sarri & Pujol, 2022).

Hands on experience is a social challenge that has consistently remained unsolved in today's learners in our education systems. The focus of PBLS has been long overdue and the future of our learners is still unclear if PBLS is not fully adopted and implemented in our schools. There is urgent need for the use of learner-centered instructional strategies amidst the ongoing curriculum reforms in Kenya with a central focus on CBC. It is therefore imperative that teachers use learner-centered instructional strategies to develop essential competencies among learners to enable the students to fit in the 21st century society. However, performance in Physics has been low in secondary schools, especially the girls as educators often operate in a very volatile and dynamic environment. It is on the basis of this wide deepening gap of skills mismatch observed among the form 4 graduates that the current study aimed at investigating the use of Problem-Based Leaning Strategy for Learner's attainment of Critical Thinking Skills (CTS) in Public Secondary Schools in Kenya. The study pursued the following objectives:

1. To determine the extent to which instructors' use PBLS as a teaching strategy to promote problem solving abilities of girls in Physics
2. To evaluate the gain in problem solving abilities of girls in "Fluid Flow" when using problem-based learning strategy

2. Literature Review

Nuraini, Asri and Fajri (2023) argue that science teachers play an important role in assisting learners develop ideas and process skills such as experimental, observation, investigation, hypothesizing, prediction, ICT integration, drawing conclusions and communication. However, few instructors often use PBLS as one of the constructivists teaching strategy in teaching physics as opposed to convention methods.

With increasing stakeholders' current educational expectations, there is need to employ the constructivist learning strategy such as PBLS model to promote sustainable learning process in the education sector evidence has shown that teaching strategies in Kenya schools are expository and facts oriented in nature (Njoka, 2020; Bett, 2022). These strategies making students to be passive hence remain boring (Wafula, 2017) as dictated by the curriculum and the syllabus. Majority of the girls' shy away from Physics due to content approach, makes them believe learning of physics is more abstract and difficult.

A recent non-randomised study concentrated on the effects of PBL instructional method on learners critical thinking. Liu and Pásztor (2022) conducted a meta-analysis study by cross-examining 50 empirical evidences ranging from 2000 to 2021. By sampling 5,210 participants with 58 effect sizes, the credibility of their research was tested by Egger's and Begg's p-values obtained at 0.231 and 0.060 respectively illustrating lack of publication bias as p-values were > .05. Results demonstrate that the use of PBLs has greater influence on learner's ability to gain critical thinking skills in science-oriented subjects. Similar studies attest to the influence of PBLS on acquisition of critical skills (Oliveira et. al., 2016; Ding, 2016; Ulger, 2018; Wang, 2018; Liu et. al., 2020) which may not be an issue of implicit anticipation. However, Lee et. al., (2016) found contradictions in other researchers' approach, arguing the ineffectiveness of PBLS on acquisition of learner critical skills. Most of the analysed studies by Liu and Pásztor and other aforementioned researchers were social sciences and chemistry in higher institutions, the current study uses PBLS in secondary schools, especially the girls undertaking physics as one of the STEM subjects.

Wahyudi, Nurhayati & Saputri (2022) investigated the effect of PBLS on promoting CTS among teachers and results show significant improvement of CTS. Similarly, Njoka (2020) portends, there are certain skills involved in a class investigation that students must have; first, reformulating general statement that are testable, second; criticizing given experimental procedures and suggesting improvement that could be made to them, and third; devising and describing the sequences of investigation (Suh, et. al., 2023).

Sholahuddin, et. al., (2020) investigated the effect of 'cognitive style-based learning strategy' (CSBLS) in promoting processed based skills among the elementary learners in Indonesia. They sampled two schools, one which was best school and the other one was good school. The researchers used the CSBLS method for a period of five weeks in physics lessons for elementary learners of grade six in the range of 10 to 11 years old. One school was randomized with 33 learners while the other one with 39 learners and both schools included boys and girls. Two topics of changes of substances and conductors-insulators were covered in 10 lessons and the learners were assessed using a pre-test-post-test method. The findings show that the method administered significantly improved learners' science-based process skills. However, learners' ability to demonstrate experiments and identify the guiding variables and principles or laws was somehow poor. They concluded that CSBLS caters learners' differences with unique levels of cognitive styles and development to improve critical thinking skills of the learners.

A further randomized study carried in Indonesia surveyed pre-service trainers in a private university (Saputro, et. al., 2020). The researchers tested the self-efficacy of critical thinking using PBLS. They used quasi-experimental design with control and experimental groups each n=22 individuals. The control group was taught using lecture method while the experimental group was exposed to PBLS. One instructor with experience of 6 years was used to administer the process. Data was analyzed using inferential statistics with the aid of SPSS 17.0. The findings show that PBL was statistically effective in improving the self-efficacy on critical thinking of the participants than the conventional method of teaching. On the other hand, this study investigates problem solving abilities of among Girls undertaking physics in secondary schools using PBLS.

In the same vein, Irwanto, et.al., (2019) argued that the use of science-based process skills developed by learners in finding scientific information, ability to develop critical skills such as solving problems and making decisions which improve their creativity and perception towards STEM subjects. Hence, Limatahu, Suyatno, Wasis and Prahani (2018) claim that such skills should be considered at early years and developed continuously in the learner's lifetime. These claims could be true and valid considering that the Government of Kenya is modestly phasing the 8-4-4 curriculum and implementing the Competency Based Curriculum. Teachers who had teaching experience of over 5 years were considered and trained on how to use the method.

3. Methodology

3.1 Research Design

This study investigates the use of Problem-Based Leaning Strategy on Learner's attainment of Critical Thinking Skills (CTS) in Public Secondary Schools in Kenya. The topic of Fluid Flow in physics was used in four girls' secondary schools in Bungoma County. Form-two girls undertaking physics were chosen and a nonequivalent Solomon Four Group Quasi-Experimental research design used. The selected schools were assigned the treatment and control conditions as intact groups. Four instructors with more than 5 years of teaching experience were used to administer PBLS.

The research design used was suitable for the Experimental and Quasi-experimental studies (Mohajan, 2020). It helped the study to achieve the interaction between pre-test relative to the post-test and homogeneity of the study groups before administration of treatment. The design controlled all biases to internal validity except those associated with interaction of selection and history, selection and maturation. The schools were randomly assigned control and treatment groups, the conditions under which the instruments were administered was similar across the schools for purposes of controlling interaction between selection and the instrument. The teachers who administered the intervention were trained on how to administer the treatment. Schemes of work of 4 weeks of teaching followed a post test. An instructor's guide was based on the form 2 Physics syllabus. Using a manual, teachers ensured homogeneity among the experimental groups in the exposure of learners in interventions. A common scheme was used for all the four teachers in the same topic of Fluid Flow for purposes of uniformity and syllabus coverage for all the cohorts involved.

3.2 The Participants and Sample Size Calculation

A sampled unit of learners was used from targeted 6180 form 2 learners and with 4 teachers. Two groups of each n=40 was either control or experimental exposed to pretest and post-test.

3.3 Statistical Measures

Data was collected by use of both qualitative and quantitative methods using structured interview and survey questionnaire. Four schools were grouped into experimental and control groups using simple random sampling technique. Similarly, a simple random sampling technique was used for schools with more than one stream of form 2 students to select only one stream for data collection. The study tools were validated by conducting a pilot study in 2 secondary schools with the same characteristics as sampled schools in Busia County. This aspect of piloting helped the study to identify misunderstanding, ambiguities, and inadequate items (Malmqvist, et. al., 2019; Roni, et. al., 2020). Moreover, reliability was ensured by adopting the Kunder-Richardson (KR- Formula 20) estimates at 0.75 correlation coefficient to enhance stability of the tools.

The aspect of reliability was confirmed by correlation coefficient on a rating of up to 1 and taken at correlation coefficients of or equal to 0.70. and 0.75 for Cronbach's Alpha and K20 correlation respectively. Thus, the coefficient >0.70 and >0.75 were considered desirable. Table 1 and 2 show the findings of the reliability coefficients.

3.4 The Procedure

A research permit was applied from National Council of Science Technology and Innovation (NACOSTI) and a letter from County Director of Education Office-Bungoma County to allow the study to proceed. The selected teachers were trained for 1 week on how to use PBLS to empower them with skills of using PBLS as an instructional strategy. After this period PAT pre-test was administered to experimental group 1 and control group 2 and later on followed by the exposure of PBLS. The Physics teachers in selected schools administered the Physics Attainment Test (PAT) post-test to all four groups.

3.5 Data Analysis and Presentation

The data was collected and coded for analysis. It was analyzed using descriptive and inferential statistics. Similarly, the information was presented in the form of means, standard deviation and percentages with the aid of SPSS vs. 26.0. The reliability and sampling adequacy of the study instrument was determined while the sample was tested for adequacy to demonstrate dependability of the research tools for this study.

Table 1 Item-Total Statistics for K20 and Cronbach's Alpha Reliability Coefficients

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Objective	9.8250	11.276	.672	.932

Researcher's Experimental Data, (2023)

The KR20 was used to assess the reliability of dualistic measurements, and further evaluate if items from the test attain the same right or wrong outcomes over the sampled girls. If KR-20 coefficient is < 0.75 and items with a Corrected Item-Total Correlation of < 0.30, those specific items are deleted and re-run the KR-20 analysis. From Table 1, the Cronbach's Alpha if item deleted column typically shows the KR-20 related with the question items. The KR-20 obtained for PAT= 0.932 and was more than the minimum threshold value of 0.75 hence the items were acceptable and proceeded with study analysis. Furthermore, the Item-Total Statistics column, in the Corrected Item-Total Correlation for PAT = 0.672 were more than the critical value of 0.30 hence no cause of alarm for items to be deleted. Therefore, the test to observe if data from the PAT met the assumption of reliability based on K20 show that the tools were highly reliable.

Table 2 Reliability Statistics

Cronbach's Alpha	N of Items
.924	5

Source: Researcher's Data (2023)

As presented in Table 2, the Alpha Coefficient was 0.924, which was higher than the proposed minimum of 0.70. hence, the study survey questionnaire for the students was highly reliable for making accurate predictions for this study.

Table 3 KMO and Bartlett's Test for Sampling Sufficiency

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.782
Bartlett's Test of Sphericity	Approx. Chi-Square	987.415
	Df	10
	Sig.	.000

Source: Researcher's Data, (2023)

To determine whether sampling adequacy for the study tools, KMO and Bartlett's Test were used in this study. Keiser-Meyer-Olkin measure of sampling sufficiency is a pointer of corresponding scales of the observed affiliated quantities to the partial matching constant. This test gives the minimum standard to be realized before conducting the principal component analysis. These values run from 0 to 1, with the value to close to 1 signifying superiority and a sign of good factor analysis of the variables. Ford et al., (1986) suggests a minimum value of 0.6. Results in Table 3 show that a KMO value of 0.782, implying that selected sample was sufficient for the use of statistical investigation. Bartlett's test of Sphericity usually tests the null hypothesis that states that the constructs in the sample relationship matrix could be uncorrelated. Table 3 shows the observed significant level, which was .000, relatively smaller than the set .005 level hence more grounds to reject the null hypothesis. Consequently, the strength of the relationship among the constructs was significant.

4. Results and Discussion

4.1 Instructors' Use PBLS as a Teaching Strategy to Promote Problem Solving Abilities of Girls in Physics

The study sought to determine the extent to which instructors' use PBLS as a teaching strategy to promote problem solving abilities of girls in Physics. Five positive statements were considered on a Likert scale of 1=SD, 2=D, 3=N 4=A 5=SA and results are shown in Table 4.

Table 4 Instructors' Use PBLS as a Teaching Strategy to Promote Problem Solving Abilities of Girls in Physics

Statements	1=SD		2=D		3=N		4=A		5=SA			
	F	%	F	%	F	%	F	%	F	%	M	SD
Learning of Physics is easy, fun and enjoyable with the use of PBLS	5	3.1	11	6.9	7	4.4	58	36.3	79	49.4	4.2	1.02
My teacher frequently uses active problem-based teaching and learning strategies	29	18.1	101	63.1	10	6.3	12	7.5	8	5.0	2.2	.98
I am hearing for the PBL method for the first time since joining Form 1	5	3.1	9	5.6	4	2.5	18	11.3	124	77.5	4.5	1.01
We always work in a team based and collaborate to solve physics problems and concepts	41	25.6	84	52.5	13	8.1	18	11.3	4	2.5	2.1	1.00
Physics concepts are made clear as explanations are made during group discussions & presentations among the students	7	4.4	13	8.1	9	5.6	29	18.1	102	63.8	4.3	1.16

Source: Researcher's Data, (2023)

Learning of Physics is easy, fun and enjoyable with the use of PBLS depicts the greatest challenge for the leaners as Table 4 shows that more than half, 137 (85.6%) of the girls agreed (M=4.2; SD = 1.302) and this has a bearing with the number of learners' capacity to problem solving abilities in physics. Studies have described PBLS as a method that bridges theory and practice, but there seem to be high variability in what the education stakeholders understand by this model, especially in teaching science-oriented subjects like physics (Trullàs, Blay, Sarri & Pujol, 2022). However, 130 (81.3%) of the participants disagreed that their teacher frequently uses active problem-based teaching and learning strategies (M=2.2; SD=0.98). This is a pointer that most teachers could be using conventional strategies in teaching science-oriented subjects hence students end up choosing other subjects than physics due to lack of constructivists instructional strategies in secondary schools. This trend is likely to affect their future life while choosing courses at universities or TVET. Hands on experience is a social challenge that has consistently remained unsolved in today's education systems. The focus of PBLS has been long overdue and the future of our learners is still unclear if the PBLS is not fully adopted and implemented in our schools. Evidence has shown that teaching strategies in Kenya schools are expository and facts oriented in nature (Njoka, 2020; Bett, 2022).

On the other hand, 144 (88.8%) of the participants agreed that they were hearing for the PBL method for the first time since joining Form 1 (M=4.5; SD=1.01). This totally shows that teachers use strategies that make students passive hence remain boring (Wafula, 2017) as dictated by the curriculum and the syllabus. This makes majority of the girls to shy away from Physics due to content approach, making them believe that learning physics is more abstract and difficult. With the increasing stakeholders' current educational expectations, there is need to employ the constructivist learning strategy such as PBLS model to promote sustainable learning process in the education sector (Mang'eni, et. al., 2023)

Moreover, 125 (78.1%) of the participants surveyed disagreed that they always work in a team based and collaborate to solve physics problems and concepts (M=2.1; SD=1.00). Lack of constructivist strategies pinpoint the inactive involvement of the students. constructivists teaching strategies such as problem-based learning strategy (PBLS). PBLS is a firm philosophical and epistemological foundation founded on strong trajectory in diverse disciplines of study especially the science-oriented subjects (Mang'eni, et. al., 2023).

However, 131 (81.9%) of the girls stated that Physics concepts are made clear as explanations are made during group discussions & presentations among the students (M=4.3; SD=1.16). According to Nuraini, Asri and Fajri (2023), science teachers play an important role in assisting learners develop ideas and process skills such as experimental, observation, investigation, hypothesizing, prediction, ICT integration, drawing conclusions and communication.

with the interview conducted, the teaching strategies used by our teachers have a bearing to students practical

and problem solving. Therefore, by employing PBLS, students can develop critical skills and the enrolment improve due to good performance. One interviewee said that after the exposure of this method, I developed an inner liking of physics which I had lost interest before. If this process continues, I will choose physics as one of my favourite subjects in this school.

The study tested the Ho1 that states that instructors' use PBLS as a teaching strategy does not significantly predict the problem-solving abilities of girls in Physics. A chi-square test was used to test the relationship of the variables and results are shown in Table 5

Table 5 Chi-Square Test Statistics for Instructors' Use of PBLS as a Teaching Strategy

	Learning	Frequently	Hearing	collaborate	concepts
Chi-Square	146.250[a]	194.688[a]	334.438[a]	128.938[a]	200.750[a]
Df	4	4	4	4	4
Asymp. Sig.	.000	.000	.000	.000	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 32.0.

Source: Researchers Data (2023)

A chi-square test of independence was done to observe the association between independent variables and learner's attainment of CTS. As shown in Table 5, results show that all the variables were significant, X^2 (4, N = 160) = 146.250, p = .000; X^2 (4, N = 160) = 194.688, p = .000; X^2 (4, N = 160) = 334.438, p = .000; X^2 (4, N = 160) = 200.750, p = .000. Thus, the use of PBLS as a teaching strategy promotes learner's CTS at the study area. Similar results were reported in a randomized conducted in Indonesia among the pre-service trainers in a private university (Saputro, et. al., 2020). Their findings illustrate that PBL was statistically effective in improving the self-efficacy on critical thinking of the participants than the conventional method of teaching. Although the PBL method improves learners' science-based process skills, however, Sholahuddin, et. al., (2020) finds learners' ability to demonstrate experiments and identify the guiding variables and principles or laws below expectations among the elementary learners in Indonesia.

4.2 Problem Solving Abilities of Girls in "Fluid Flow" using PBLS

The study sought to determine the gain in problem solving abilities of girls in "Fluid Flow" when using problem-based learning strategy. The learners were subjected to a test before and after the intervention and marked out 14 marks. Descriptive results are indicated in Table 6.

Table 6 Girls Problem Solving Abilities in Fluid Flow using PBLS

		N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean LB	95% Confidence Interval for Mean UB	Min	Max
A1	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.18	.395	.084	1.01	1.36	1.00	2.00
	11-14 Marks	4	2.00	.000	.000	2.00	2.00	2.00	2.00
	Total	**40**	**1.20**	**.405**	**.064**	**1.07**	**1.33**	**1.00**	**2.00**
A2	0-3 Marks	3	1.33	.577	.333	-.10	2.77	1.00	2.00
	4-6 Marks	11	2.46	.522	.158	2.10	2.81	2.00	3.00
	7-10 Marks	22	3.68	.477	.102	3.47	3.89	3.00	4.00
	11-14 Marks	4	4.00	.000	.000	4.00	4.00	4.00	4.00

	Total	**40**	**3.20**	**.912**	**.144**	**2.91**	**3.49**	**1.00**	**4.00**
B1	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.27	.456	.097	1.07	1.48	1.00	2.00
	11-14 Marks	4	2.00	.000	.000	2.00	2.00	2.00	2.00
	Total	**40**	**1.25**	**.439**	**.069**	**1.11**	**1.39**	**1.00**	**2.00**
B2	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.32	.477	.102	1.11	1.53	1.00	2.00
	11-14 Marks	4	2.00	.000	.000	2.00	2.00	2.00	2.00
	Total	**40**	**1.28**	**.452**	**.072**	**1.13**	**1.42**	**1.00**	**2.00**
C1	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.55	.596	.127	1.28	1.81	1.00	3.00
	11-14 Marks	4	3.00	.000	.000	3.00	3.00	3.00	3.00
	Total	**40**	**1.50**	**.716**	**.113**	**1.27**	**1.73**	**1.00**	**3.00**
C2	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.73	.467	.141	1.41	2.04	1.00	2.00
	7-10 Marks	22	2.68	.568	.121	2.43	2.93	2.00	4.00
	11-14 Marks	4	4.00	.000	.000	4.00	4.00	4.00	4.00
	Total	**40**	**2.43**	**.903**	**.143**	**2.14**	**2.71**	**1.00**	**4.00**
D1	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.50	.512	.109	1.27	1.73	1.00	2.00
	11-14 Marks	4	2.75	.500	.250	1.95	3.55	2.00	3.00
	Total	**40**	**1.45**	**.639**	**.101**	**1.25**	**1.65**	**1.00**	**3.00**
D2	0-3 Marks	3	1.00	.000	.000	1.00	1.00	1.00	1.00
	4-6 Marks	11	1.00	.000	.000	1.00	1.00	1.00	1.00
	7-10 Marks	22	1.23	.429	.092	1.04	1.41	1.00	2.00
	11-14 Marks	4	2.00	.000	.000	2.00	2.00	2.00	2.00
	Total	**40**	**1.23**	**.423**	**.067**	**1.09**	**1.36**	**1.00**	**2.00**

Researcher's Experimental Data, (2023)

Results in Table 6 show that the performance of the Girls in school C was slightly better than the other schools before the intervention of PBLS. After the intervention of the PBL method, the performance of the Girls in school A (M = 3.2, SD = .912) and C (M = 2.43, SD = .903) was better than school B (M = 1.28, SD = .452) and D (M = 1.23, SD = .423) in the same topic. However, school A and C improved significantly after the exposure of PBLS by 62.5% and 38.14% respectively. There seems to be minimal or no improvement by the performance of the Girls in school B and D. It should be noted that these two schools performed below expectations before and after the exposure to PBLS. For instance, school A had a minimal improvement of 1.96%

while the performance of school D dropped by 18.37% after the intervention. These results point out that even though PBLS has the capacity to improve critical skills among the learners, however, its impact is likely to be affected by teacher's pedagogical challenges. This is because PBLS should resonate with the teacher and also learner's perception of the method is very critical. Similarly, we can deduce that teachers may not be using constructivist teaching strategies as demonstrated by the performances of the selected girls' schools at the study area. It should also be understood that learners come from diverse backgrounds and that they do not all learn in the same way. Therefore, learners' differences are also likely to affect the use of this teaching strategy. Such differences are likely to impact negatively the science based process skills (Irwanto, Rohaeti & Prodjosantoso, 2019) which are very critical in improving learners' creativity and problem solving abilities.

The current results also indicate that school A and C learners may have had prior exposure to PBLS in the former classes while school B and D learners were being exposed to this strategy for the first time. However, teachers might also have administered the instructional strategy inappropriately. Therefore, learners' critical skills can be enhanced initially when suitable learning approach is used. In line to these findings, Sholahuddin, et.al., (2020) observed that learners' science-based process skills improved significantly after the use of PBLS among the elementary school learners in Indonesia. The results are also similar to those of Liu and Pásztor (2022) non-randomised of meta-analysis that found the use of PBLs has greater influence on learner's ability to gain critical thinking skills in science-oriented subjects. Other studies attest the influence of PBLS on acquisition of critical skills (Oliveira et. al., 2016; Ding, 2016; Ulger, 2018; Wang, 2018; Liu et. al., 2020) which may not be an issue of implicit anticipation.

The study further tested the Null Hypothesis (Ho_2): That there is no significant difference in problem solving abilities towards learning of Fluid Flow between girls who are exposed to PBLS and those taught using conventional methods. Analysis of variance was used to compare the variability in the test scores between the different schools and the variability within each school. Results are confirmed in Table 7.

Table 7 ANOVA Results for Problem Solving Abilities in "Fluid Flow" using PBLS

		Sum of Squares	Df	Mean Square	F	Sig.
A1	Between Groups	3.127	3	1.042	11.467	.000
	Within Groups	3.273	36	.091		
	Total	6.400	39			
A2	Between Groups	24.233	3	8.078	35.608	.000
	Within Groups	8.167	36	.227		
	Total	32.400	39			
B1	Between Groups	3.136	3	1.045	8.625	.000
	Within Groups	4.364	36	.121		
	Total	7.500	39			
B2	Between Groups	3.202	3	1.067	8.051	.000
	Within Groups	4.773	36	.133		
	Total	7.975	39			
C1	Between Groups	12.545	3	4.182	20.195	.000
	Within Groups	7.455	36	.207		
	Total	20.000	39			
C2	Between Groups	22.820	3	7.607	30.582	.000
	Within Groups	8.955	36	.249		
	Total	31.775	39			
D1	Between Groups	9.650	3	3.217	18.528	.000
	Within Groups	6.250	36	.174		
	Total	15.900	39			
D2	Between Groups	3.111	3	1.037	9.664	.000
	Within Groups	3.864	36	.107		
	Total	6.975	39			

Researcher's Experimental Data, (2023)

The ANOVA test was used to examine causes of variability in data observation in terms of variability between groups and variation within the groups and variance in total observations. The choice of ANOVA test to this hypothesis was preferred than other test like Multiple t-tests in this study because ANOVA minimizes the Type I errors (errors due to chance) unlike the t-test statistic (Gray et al., 2017). The p-value in the test gives useful direction on whether we can reject or retain null hypothesis (Ho_2) in the test. A significance level of 0.05 is used to validate the claim of the hypothesis in satisfying ANOVA assumptions. However, according to (Polit & Beck, 2018), variability within groups is compared to variability between groups using the F-ratio (F-statistic). If the observations are true with null hypothesis, then no statistically difference shown between groups whereby F-statistic is closer to 1. Moreover, a larger F value illustrate that the difference between groups with independent construct(s) is genuine (Mishra, et. al., 2023). A significance p-value of < 0.05 implies that the means of the groups vary from one other by large amount for the difference to be statistically significant.

As shown in Table 7, the Girls problem solving abilities in the topic "Fluid Flow" using PBLS for the control and

experimental groups among the 4 schools had significant positive regression weights, showing the use of PBLS improved Girl's problem-solving abilities unlike the conventional methods in learning physics concepts. A one-way ANOVA as presented in Table 7 indicate that the significance value was 0.000 (i.e., $p = .001$) for all the 4 schools, which is below the set value of 0.05. Therefore, the performance of the girls differed significantly between groups and school since $p < .001$ is less than the chosen significance level $\alpha = 0.05$.

Similarly, the F ratios calculated were larger than the F-table values indicating that there is more variability between the groups (cause by the independent construct) than there is within each group (error term). The ANOVA F statistic tests for schools (A1 = 11.467; A2 = 35.608; B1 = 8.625; B2 = 8.051; C1 = 20.195; C2 = 30.582 and D1 = 18.528; D2 = 9.664) respectively. The model as a whole was significant as the critical F-value calculated was higher than the critical table value of 2.866 ($F_{calculated} > F_{table}$ value). The results illustrate statistically significant difference between variables of Girls' problem solving abilities in physics as determined by the one-way ANOVA (F(3,39) = (A1 = 11.467; A2 = 35.608; B1 = 8.625; B2 = 8.051; C1 = 20.195; C2 = 30.582 and D1 = 18.528; D2 = 9.664), p = .000). Since the F-statistics were greater than the critical value (2.866), the study rejects the null hypothesis in favour of the alternate hypothesis and deduce that there is significant difference in the level of Girls problem solving abilities towards Fluid Flow, a topic in physics between students who were exposed to PBLS and those taught using conventional methods.

Similarly, Wahyudi, Nurhayati & Saputri (2022) find PBLS promoting CTS among teachers with greater expectations. However, Lee et. al., (2016) found contradictions in other researchers' approach, arguing the ineffectiveness of PBLS on acquisition of learner critical skills. Most of the analysed studies by Liu and Pásztor and other aforementioned researchers were social sciences and chemistry in higher institutions. This paper uses PBLS in secondary schools especially the girls undertaking physics as one of the STEM subjects. It was found out that there is a statistically significant difference in the mean performance of physics in the topic 'Fluid Flow' between the different groups of students in the 4 selected schools in Bungoma county.

Furthermore, the study analysed the qualitative data and findings are as follows from the interviews:

One of the questions that was asked during the interviews in the four schools was, "Can learners taught through Problem Based Learning Strategy demonstrate problem solving abilities in physics achievement?". The participants said that PBLS is a more efficient way to learn lifelong skills in practical lessons and place the learner as much as possible in the position of being an innovator. The learner then brings in class the skill of imagination, curiosity and problem solving

5. Conclusion and Recommendations

5.1 Conclusion

The evidence found in this paper illustrate that PBLS significantly predict the problem-solving abilities of learners as reflected with the topic of 'Fluid Flow' in physics at the study area. However, results show inadequate use of the PBLS among the teachers teaching physics in the study area. The curriculum now demands for re-alignment of pedagogical skills with upgrading/upskilling of teachers to accurately deliver the new curriculum objectives. This is a policy issue which should be looked into by the government and policy framework for effective implementation of CBC programme in the education systems in Kenya.

5.2 Recommendations

The study recommends that:

1. The Government of Kenya should consider with the interest of the CBC, capacity build the teachers and support them for the adoption and use of PBLS as a teaching strategy.
2. The education implementers should encourage learner –entered activities and heuristic strategies to develop CTS among the learners
3. Allocation of adequate resources should be key in the process of Curriculum implementation in secondary schools

Study Limitation

This study was only limited to Girls' schools with regard to the effect of PBLS on learner's acquisition of CTS. However, further studies can be done to boys' schools and other subjects to triangulate and validate the current findings in this paper

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