Problem-Based Learning: An Approach for Fostering Critical Thinking Skills Among Secondary School Physics Students' in Isiolo Sub County, Kenya

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ABSTRACT

Physics provides the conceptual and methodological foundation upon which many other scientific fields are built up on. Despite its importance, students' academic achievement in physics in Isiolo Sub County has generally been poor partly due to their low critical thinking skills. Teaching approaches have been cited as one of the factors that influence students' critical thinking skills. This study investigated effects of problem-based learning (PBL) approach on students' acquisition of critical thinking skills in physics in public co-education secondary schools in Isiolo Sub County, Kenya. The study adopted Solomon Four Quasi Experimental research design. The accessible population comprised 265 form two students. Simple random sampling techniques were used to select 4 co-educational secondary schools and a sample of 128 form two students who took part in the study. Critical Thinking Skills Physics Test (CTSPT) was used to collect data. Face and content validity of CTSTP was checked through expert judgment and its estimated reliability was 0.741. The Statistical Package for Social Science aided data analysis. Analysis of Variance (ANOVA) and t-test were used to test hypothesis at $\alpha = .05$ level. The findings indicated that the difference between critical thinking skills of students exposed to PBL and those taught using conventional methods was statistically significant, $F(3, 124) = 10.267$, $p<.05$. The paper concludes that PBL improves students' acquisition of critical thinking skills as compared to regular teaching methods. These findings may assist Physics teachers improve learners' acquisition of physics critical thinking skills and performance in the subject. The findings may also assist physics teacher trainers in strengthening PBL components in their training programmes. This may contribute to equipping teacher trainees with pedagogical skills that can nurture and develop their learners' critical thinking skills.

Keywords: Approach, Critical Thinking skills, Fostering, Problem Based Learning, Secondary School Physics Students

INTRODUCTION

Physics is a branch of science concerned with understanding the nature and behaviour of the physical world. It examines the causes of natural phenomena and seeks to explain the laws and principles governing matter, energy, motion, and force (Misoga, 2023). As a discipline, physics provides the conceptual and methodological foundation upon which many other scientific fields are built (Wati et al., 2023). Its theories have facilitated significant scientific and technological breakthroughs that underpin modern life. Major forms of agricultural mechanization rely on principles of physics, contributing substantially to improved productivity across many economies (Tagutanazvo et al., 2022). Similarly, development of transformative technologies, such as the television, computers, telecommunications systems, and medical imaging devices, have been attributed to advances in physics (Owusu, & Antwi, 2022). Contemporary innovations such as the Global Positioning System (GPS) and holographic security technologies also draw heavily on physics principles.

The centrality of physics to scientific and technological progress explains why countries prioritize the subject within their educational and economic agendas. In Kenya, physics is aligned with national development goals as articulated in Vision 2030, which aims to transform the country into an industrialized, knowledge-driven,

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middle-income economy by the year 2030 (Ministry of Education [MOE], 2023). The Vision emphasizes the critical role of Science, Technology, and Innovation (STI) in accelerating economic growth, enhancing social welfare, and strengthening governance systems. To achieve these aspirations, Kenya seeks to develop a workforce equipped with advanced problem-solving abilities, technological competencies, and innovative capacities, skills that are strongly supported by a solid grounding in physics (Kibe, 2021). Physics is therefore taught across secondary schools, tertiary institutions, and universities in Kenya.

Physics is compulsory during the first two years at secondary level in Kenya, thereafter, learners decide whether to continue with it during their third and fourth years under the 8-4-4 education system (Rutto et al., 2023). Secondary school physics curriculum seeks to: equip learners with problem-solving skills; develop capacity for constructing scientific devices from available resources; enhance technological and industrial development; promote critical thinking abilities; demonstrate the importance of physics in health and wellbeing; and prepare learners for further education and training (Kenya Institute of Curriculum Development [KICD], 2021). These objectives underscore the significance of physics in supporting national development goals and fostering scientific literacy. Despite its importance, performance in secondary school physics remains a global concern. Studies from different contexts report persistently low achievement (Gumirizah et al., 2023; Hidayati et al., 2024, Wati et al., 2023). Lantajo and Tipolo (2019) found that students in the Philippines performed poorly in physics due to weak science culture, curriculum deficiencies, inadequate instructional resources, and ineffective teaching practices. In Nigeria, an analysis by Onudibia et al. (2019) revealed average scores of 43% in physics with performance declining over time. Ethiopian studies similarly show that learners' achievement in physics is significantly below the minimum competency levels set by the Ministry of Education (Aragaw et al., 2022). In Uganda, physics has consistently recorded the lowest performance among science subjects at the lower secondary level, with only 9.7% of candidates attaining credit or distinction in 2022 (Uganda National Examinations Board [UNEB], 2023).

Kenya exhibits similar trends as data from the Kenya National Examinations Council (KNEC) between 2019 and 2024 show that the national mean score in physics ranged between 29.70% and 35.52%, far below the expected 50% benchmark (KNEC, 2021, 2025). Student' academic achievement at the county level mirrors the national situation. In Isiolo County, physics results between 2020 and 2024 were below 40%, with a declining trend noted in 2020 and 2021 (KNEC, 2023). Sub-county comparisons further reveal that Isiolo Sub-county consistently recorded the lowest performance relative to Merti and Garbatula. These patterns point to a persistent challenge requiring targeted educational interventions.

Several factors have been linked to poor performance in physics, including inadequate instructional materials, teacher qualifications, school leadership, learning environment, and low levels of critical thinking skills (Basweti, 2019; Putri et al., 2024). Among these, limited critical thinking abilities have emerged as a key determinant. According to KNEC (2025), many students struggle with questions that require higher-order cognitive skills such as analysis, evaluation, and application.

Critical thinking is an intellectually disciplined process involving observation, conceptualization, analysis, synthesis, evaluation, and application of information to guide belief and action (Su, 2023). It requires clarity, accuracy, relevance, logical reasoning, depth, and fairness. In physics, critical thinking enables learners to interpret data, analyze physical situations, solve complex problems, and draw sound conclusions (Spector & Ma, 2019). Without these skills, students often rely on rote memorization, which limits their ability to apply concepts in unfamiliar contexts. The introduction of the Competency-Based Curriculum (CBC) in Kenya underscores the need for learners to acquire and apply higher-order thinking skills to address real-life problems (Jane et al., 2020; Diana, 2020). Physics, with its abstract concepts and demanding analytical requirements, necessitates strong critical thinking skills for effective learning and improved performance (Hasbi et al., 2024).

Studies indicate that acquisition of critical thinking skills is influenced by curriculum design, learners' prior experiences, motivation, social factors, and more importantly the teaching methods employed by teachers (Putri et al, 2024, Suprapto et al, 2024). However, traditional teacher-centered methods, characterized by lecture, note-taking, and limited interaction, continue to dominate many classrooms (Wati et al., 2023). These methods tend to minimize student engagement, restrict inquiry, and hinder development of higher-order thinking skills. Consequently, researchers advocate for alternatives that promote active learning and cognitive development.

Problem-Based Learning (PBL) has emerged as a promising pedagogical approach. It involves engaging students with real-world problems to facilitate learning of concepts and development of analytical and reflective abilities.

PBL encourages collaborative learning, independent inquiry, hypothesis generation, problem analysis, and synthesis of knowledge (Gumisirizah et al., 2024). Evidence suggests that PBL enhances critical thinking skills, motivation, and academic performance across diverse subjects, including physics (Jabarullah & Hussain, 2019; Tran, 2019; Wang, et al. 2025).

Given the persistently low performance in physics in Isiolo Sub County and documented influence of critical thinking on learning outcomes, the use of PBL presents a potential strategy for fostering students' mastery of physics concepts, acquisition of critical thinking skills and achievement in the subject. This study therefore investigated the effect of PBL on secondary school students' acquisition of physics critical thinking skills, with focus on Measurement II. This topic was selected because learners have difficulties interpreting measurements and reporting them (Wanjala et al, 2020; Ngatia, 2019). The Kenya National Examinations Council (2023) has similarly highlighted frequent student errors in tasks related to measurement, reinforcing the need for targeted interventions in this area.

Objective and Hypothesis

The objective of this study was to examine the effects of problem-based learning approach on secondary school students' acquisition of physics critical thinking skills in Isiolo Sub County, Kenya. A hypothesis which stated that the difference in critical thinking skills achievement between students taught using PBL and those taught using conventional methods is not statistically significant was drawn from the objective and tested.

METHODOLOGY

This quantitative study employed a quasi-experimental Solomon Four Non-Equivalent Control Group design, which allowed for both pretest–posttest and posttest-only comparisons. The design is suitable for educational research involving intact classes and helps control for pretest sensitization effects (Khazaei et al., 2025). Data was collected in Isiolo sub-county among Form Two students in public co-educational secondary schools. Simple random sampling was used to select four schools which took part in the study. The schools were randomly assigned to two experimental groups (E1, E2) and two control groups (C1, C2). The accessible population was 265 students, from which a sample of 136 students was drawn as follows (E1 = 40; E2 = 27; C1 = 39; C2 = 30).

Instrumentation comprised a 40-item multiple-choice Critical Thinking Skills Physics Test (CTSPT). The test had items for measuring analysis, synthesis, evaluation, and application skills, aligned with the national physics curriculum, and a physics teachers teaching manual for the PBL intervention. Face and content validity of CTSPT was established through expert review. The internal consistency of CTSPT was also estimated using the Kuder Richardson (KR-20) formula. It revealed an acceptable level with a coefficient of 0.741.

Data collection followed institutional ethical clearance and local permissions culminating into the issuance of a research permit. CTSPT pretest was administered to E1 and C1; the PBL intervention was delivered over three weeks in the experimental groups, while control groups received conventional instruction. The posttest was administered to all the four groups. Data was cleaned and analyzed with the aid of Statistical Package for Social Science (SPSS). Independent-samples t-tests and one-way ANOVA were used to test differences between means at the .05 level of significance,

RESULTS AND DISCUSSION

Pretest

The entry behavior of the students was examined by pretesting groups E1 and C1 on acquisition of critical thinking skills before commencement of the study. Pre-testing helped in ascertaining whether the study groups were homogeneous at the point of entry. This is one of the assumptions of Solomon 4 quasi-experimental Non-Equivalent group research design adopted by this study (Khazaei et al., 2025). Students' critical thinking skills pre-test mean scores of groups C1 and E1 were compared using the t-test. The difference between the critical thinking skills mean score of E1 ($M = 7.63$, $SD = 2.63$) and ($M = 6.62$, $SD = 2.51$) of C1 was not statistically significant, $t(77) = 1.746$, $p>.05$. These results are evidence that the two groups were homogenous before commencement of the research. The groups were therefore suitable for the study given that this is a requirement of the Solomon Four Non-Equivalent group design.

Difference in Student's Acquisition of Critical Thinking Skills in Physics by Learning Approach

Difference in critical thinking skills was determined by comparing CTSPT posttest mean scores by learning approach. Critical thinking skills mean scores of E1, E2, C1, and C2 were computed and used to determine the differences between the control and experimental groups. The mean score of each group was computed by summating scores of the 4 elements, analysis, evaluation, synthesis and application, of critical thing skills. The mean scores of E1, E2, C1 and C2 were 19.44 (SD = 6.67) 19.19 (SD = 3.76), 14.20 (SD = 4.78 and 15.27(SD = 4.41). An examination of these results show the overall critical thinking skills mean scores of the experimental groups, E1 and E2, were higher than those of the control groups C1 and C2. This suggests that PBL enhanced students' critical thinking skills.

Gain analysis

Gain analysis was conducted to give an insight into the relative effects of treatment on groups that were pretested. Gain is the difference between the pre-test and post-test mean scores, and is an indicator of changes in groups after undergoing treatment. The gains made by groups E1 and C1 and test of their difference are summarized in Table 1.

Table 1 *Comparison of Students' Critical thinking Skills Mean Gain between the Control and Experimental Groups*

Category	N	Mean gain	SD	df	t-value	p-value
Experimental	36	11.81	6.80	69	2.557	.013
Control	35	7.58	5.41			

Critical values (df = 70, t = 1.994, p = .05)

Calculated values (df = 69, t = 2.557, p = .013)

The results reveal that the difference between the mean gain of E1 (M = 11.81, SD = 6.80) and that of C1 (M = 7.58, SD = 5.41) was statistically significant, t (69) = 2.557, $p < .05$. It means that the improvement in the treatment group was significantly higher than that of the control. It suggests that PBL was more effective in improving students' critical thinking skills than conventional teaching methods.

Poststest Difference using ANOVA

Additional analysis was conducted by testing for difference in posttest critical thinking skills between students taught using PBL and those taught using conventional methods. The posttest mean scores of groups E1 (M = 19.44, SD = 5.72, E2 (M = 19.19, SD = 3.76), C1 (M = 14.20, SD = 4.78) and C2 (M = 15.27, SD = 4.41) were compared using the ANOVA test.

Table 2 *Differences in students' Critical Thinking Skills Achievement Post-Test Scores among E1, E2, C1, and C2.*

Group	Sum of Squares	df	Mean Square	F-ratio	p-value
Between Groups	708.5	3	236.167	10.267	.000
Within Groups	2852.43	124	23.003		
Total	3560.93	127			

Critical values: (df = 3, 120, F= 2.680, p = .05)

Calculated values (df = 3, 124, F = 10.267, p = .000)

These results reveal that the difference among the means scores of E1, C1, E2, and C2 were statistically significant at the .05 level, $F(3,124) = 10.267$, $\rho < .05$. The ANOVA test results only showed that there was a statistically significant difference among the groups, but it did not reveal where the differences were. Further analysis was done to reveal the groups with statistically significant differences using the Least Significant Difference procedure (LSD).

Table 3 *LSD Pairwise Comparisons of Students' Critical Thinking Skills mean scores by Teaching Approach*

Paired group		Mean Difference (I – J)	p-value
I	J		
E1	E2	0.26	.997
E1	C1	5.24	.000
E1	C2	4.18	.008
E2	C1	4.99	.001
E2	C2	3.92	.027
C2	C1	1.07	.850

Table 3 shows that the difference between pairs E1 and C1 ($p < .05$), E1 and C2 ($p < .05$), E2 and C1 ($p < .05$), and E2 and C2 ($p < .05$) were statistically significant. However, the difference between pairs E1 and E2 ($p > .05$), and C1 and C2 ($p > .05$) were not statistically significant. These results imply that the groups E1 and E2 were similar, similarly C1 and C2 were comparable. The findings further show that the mean scores of the experimental groups were higher and significantly different from those of the control groups. The enhanced performance of the experimental groups could be attributed to the treatment.

Posttest analysis using t-test

Further analysis was carried out by comparing the mean score of combined treatment groups (E1 and E2) and that of control groups (C1 and C2) using the t-test.

Table 4 *Comparison of students' Critical thinking Skills post-test Mean score between Control and Experimental Groups*

Category	N	Mean	SD	df	t-value	p-value
Experimental	63	19.33	4.94	126	5.498	.000
Control	65	14.69	4.61			

Critical values (df = 120, t = 1.980, p = .05)

Calculated values (df = 126, t = 5.498, p = .000)

The t-test results indicate that the combined experimental group posted a higher mean (M = 19.33, SD = 4.94) than the control group (M = 14.69, SD = 4.61). The results further show that the difference between the two means was statistically significant in favour of the experimental group, $t(126) = 5.498$, $p < .05$. All the comparisons of post-test critical thinking skills done using ANOVA, t-test and the gain analysis revealed statistically significant differences in favour of the experimental group. These results do not support the hypothesis which stated that the difference between the critical thinking skills of students taught through the PBL approach and those taught using other methods was not statistically significant.

The pre-test analysis showed that E1 and C1 were similar before commencement of the study. However, after the intervention, the critical thinking skill levels of the experimental groups were higher and significantly different from those of the control groups. This means the PBL approach was more effective at improving students' acquisition of critical thinking skills compared to conventional methods. These findings are in harmony with those of a study conducted in Sumatra by Rozi et al. (2021) which showed that PBL enhanced students'

Physics critical thinking skills. The study attributed the improvement in critical thinking skills to the fact that PBL provides learners with opportunities to analyze problems and resolve them. These findings also support those of Wang et al. (2025) who observed that discussions in the realm of problem-solving had a positive impact on students' abilities to think critically. They also noted that the students' arguments during the PBL activated their critical thinking skills. Rutto et al. (2023) assert that PBL enhances critical thinking because it is rich in debates, and provides students with opportunities to elaborate their answers by giving critical and logical explanations.

This study has demonstrated that PBL is effective in improving students' critical thinking skills. However, other studies have noted results that are contrary to this one. Lapuz and Fulgencio (2020) established that there is no differential effect of PBL on the student's critical thinking skills. Mang'eni et al. (2023) noted that PBL sometimes does not improve students' critical thinking because of its shortcomings. The shortcomings included; tendency by students to get frustrated easily when carrying out investigations, reduced access to questions from teachers, and reduced confidence when learning independently. Fadilla et al. (2021) contend that adoption of PBL is not a guarantee that students' critical thinking skills will be improved. Critical thinking skills are enhanced only when teachers and students apply each stage of PBL well. The approach enhances critical thinking skills only if groups or teamwork are well organized, as this provides students with the opportunity to empower, hone, test, and develop ability to think continuously.

Physics is considered one of the hardest subjects in secondary schools, it is believed that only gifted students understand its concepts and practices which require critical thinking skills (Gumisirizah et al., 2023). These findings show that PBL improves students' physics critical thinking skills. PBL improves critical thinking skills because it is a student-centered teaching approach that promotes analysis, evaluation, understanding, and application of the concepts, rather than recall of factual knowledge (Hidayati et al., 2024). This implies that the PBL can be used with other teaching approaches in secondary schools to enhance students' acquisition of knowledge, critical thinking skills and performance in physics.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The results revealed statistically significant differences in CTS achievement in favour of the experimental group. This paper concludes that PBL approach is more effective in developing learners' critical thinking abilities than conventional teacher-centred methods. Students exposed to PBL demonstrated superior abilities in analyzing problems, synthesizing concepts, and evaluating solutions, which are central to higher-order cognitive development in physics. The results substantiate the theoretical foundations of constructivism, which posit that active learner engagement through problem-solving and inquiry enhances conceptual understanding and reasoning. By encouraging learners to collaborate, question assumptions, and reflect on multiple solutions, PBL cultivates an environment that promotes intellectual curiosity and metacognitive awareness. The evidence from this study therefore confirms that PBL is not only pedagogically sound but also empirically effective in fostering the critical thinking skills necessary for scientific literacy and innovation.

Recommendations

Based on the findings, it is recommended that secondary school physics teachers integrate problem-based learning as a core instructional strategy. The KICD and the MOE should consider embedding PBL principles within the secondary school physics curriculum to promote critical and reflective thinking. Additionally, teacher education programs should emphasize PBL methodologies to equip educators with the necessary skills to design and implement inquiry-driven lessons, and critical reasoning.

Ethical Considerations

Before the data collection process, approval was granted by the Egerton University Ethics Committee, a permit from NACOSTI was obtained and clearance from relevant education managers in Isiolo Sub County was given. In addition, the participants were informed about the research objectives and procedures, and their consent to participate in the study was sought. The participants were also informed that they were free to withdraw from the study at any time they felt like. Anonymity and confidentiality were ensured by restricting access to the provided data using locked cabinets and passwords. Attempts were made to minimize plagiarism by listing in reference list all the sources cited in the paper.

Declaration of Interests

This research did not receive any funding.

Conflict of Interests

The authors declare that they have no competing interests.

Data Availability Statement

Data used in this study will be availed on request.

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