



EFFECTS OF A SHORT-TERM TEACHER PROFESSIONAL DEVELOPMENT ON PHYSICS LEARNING UNDER SEVERE RESOURCE CONSTRAINTS: CONCEPTUAL AND SYMBOLIC GAINS WITHOUT PROCEDURAL IMPROVEMENT

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Abstract

Physics teaching in SubSaharan Africa often remains theoretical because of a lack of teaching materials and limited access to teacher training, and evidence on lowcost, shortterm professional development in such fragile contexts is scarce. This quasiexperimental study was conducted in ten secondary schools in MbanzaNgungu, Democratic Republic of Congo, with five schools assigned to an experimental group and five to a control group. The sample included 248 students and ten physics teachers from those schools. Data collection relied on a validated tenitem test measuring conceptual, procedural and symbolic dimensions of physics learning, complemented by semistructured teacher interviews. The theoretical framework combined three pillars: the use of lowcost didactic materials, situated learning as conceived by Lave and Wenger, and Bandura's concept of teacher selfefficacy. The main results show that students taught by trained teachers significantly outperformed control students on the conceptual dimension (Cohen's $d = 0.49$) and the symbolic dimension ($d = 1.58$), whereas no significant difference was observed in procedural skills. Persistent errors in algebra, unit conversion, and graphical interpretation remained in both groups. Teachers in the experimental group reported higher selfefficacy but their teaching practices changed in variable ways across individuals. An implication of these findings is that even shortterm professional development can improve conceptual and symbolic learning under severe resource constraints, yet procedural fluency likely requires stronger collaboration between physics and mathematics teachers as well as longer or more targeted interventions.

Keywords: *teacher, professional development, didactic materials, physics education, pedagogical transformation, situational learning, student achievement, Sub-Saharan Africa*

Introduction

The teaching and learning of physics at the secondary level face persistent challenges worldwide. Pedagogical, structural, and technological shortcomings hinder both conceptual understanding and student engagement (Onweh & Akpan, 2014). In lowresource contexts, where education budgets are minimal and quality infrastructure is scarce, these difficulties are particularly acute (Global Education Monitoring Report Team, 2023). A further complication arises from the disconnect between curriculum intentions, which are generally oriented toward competency development, and classroom practices, which remain predominantly theoretical and lecturebased (Abrahams et al., 2013).

SubSaharan Africa exemplifies this predicament. Schools in the region contend with a pronounced lack of functioning laboratories, insufficient teaching materials, gaps in teacher initial training, limited proficiency with technological tools, overcrowded classrooms, and deteriorating infrastructure (Bansimba et al., 2026; Bazangika et al., 2025; DarlingHammond et al., 2017; Ogunniyi, 2004). Under such conditions, physics education is often reduced to the transmission of abstract content, whereas the discipline is inherently exploratory and grounded in observable phenomena.

Several recent studies show that teacher professional development can help. Training programs that include new methodologies and digital tools can improve how teachers design their lessons and respond to students' needs (Fazio & Logman, 2024; Guerrero Zambrano et al., 2025). Teacher selfefficacy matters too. When teachers believe they are capable, they adopt new practices more easily, and student outcomes tend to improve (Lin & Luo, 2023). Teachers with strong selfefficacy are more resilient, more autonomous, and more likely to use studentcentered approaches (Azila Gbetteor et al., 2021; Basileo et al., 2024).

Despite this evidence, few studies have examined whether very shortterm professional development programs, lasting only a few days, can produce measurable gains in student achievement in resourceconstrained African contexts. Furthermore, existing research rarely distinguishes between different cognitive dimensions of physics learning, such as conceptual understanding, procedural fluency, and symbolic reasoning. The present study addresses these gaps.

Theoretical Framework

This study is grounded in three interconnected theoretical pillars: the role of didactic materials in science education, the principles of situational learning, and teacher self-efficacy. These concepts guide the design of the professional development program and inform the interpretation of student outcomes across conceptual, procedural, and symbolic dimensions (Bandura, 1997; Brahmia & Olsho, 2023; Redish & Kuo, 2015).

Didactic Materials

Didactic materials include all resources made available to teachers and students to facilitate the teaching and learning of scientific concepts, procedures, and representations (Thingholm, 2015). In physics education, such materials take various forms. Concrete materials include measuring instruments, physical models, and laboratory apparatus. Symbolic materials comprise diagrams, graphs, equations, and visual representations. Digital resources encompass simulation software, interactive platforms, and virtual laboratories.

The pedagogical significance of didactic materials is well documented. When thoughtfully integrated into teaching sequences, they promote conceptual understanding by allowing students to interact with phenomena directly rather than through verbal description alone (McLoughlin et al., 2024). Through problem solving activities and data interpretation, they support the development of procedural skills. They also contribute to reducing learning inequalities by contextualizing abstract knowledge in concrete, accessible formats.

For this study, didactic materials were operationalized through the fabrication of low-cost local resources, including simple circuit boards and recycled generator models. These materials were embedded within situation-based lessons on electric generators and receivers.

Situational Learning

Situational learning, as articulated by Lave and Wenger (1991), conceptualizes learning as a process of active engagement in authentic social practices. Learners construct knowledge not through passive reception but through participation in meaningful activities situated in real world contexts. Jonnaert (2009) extends this view, describing the situational approach as a constructivist model in which learners build understanding through interaction with complex, contextualized situations.

In this framework, a situation refers to a structured set of elements (problems, constraints, resources, and objectives) that anchors knowledge in learners' lived experience. The pedagogical aim is to foster transferability: developing in learners the capacity to mobilize knowledge appropriately across varied contexts. Bansimba et al. (2026) operationalize this idea by embedding learners in adaptive ecological simulations where scientific reasoning emerges from locally relevant environmental dilemmas. In physics education, this implies designing learning experiences in which scientific principles emerge from and return to the phenomena students encounter in their daily lives.

The situational approach aligns with curricular reforms undertaken in the Democratic Republic of Congo since 2018, which promote competency-based teaching and emphasize contextualized teaching rooted in students' experiential worlds (Jonnaert, 2011, 2018). Within this framework, didactic materials are not neutral supports but embedded resources that mediate action, reflection, and knowledge construction.

In the present intervention, situational learning was implemented through authentic problem scenarios. For example, students were asked to diagnose why lamps in a house no longer light up, a task requiring the application of concepts related to electric generators, receivers, and circuit analysis.

Teacher Self-Efficacy

Self-efficacy refers to an individual's belief in their capacity to execute actions required to achieve specific goals (Bandura, 1977, 1997). Within Bandura's social cognitive theory, self-efficacy is distinct from actual competence; it concerns perceived capability rather than demonstrated skill. This perception influences how people think, feel, motivate themselves, and act.

Self-efficacy develops through four principal sources. Mastery experiences (successful completion of tasks) provide the most authentic evidence of capability. Vicarious experiences, or observing similar others succeed, can strengthen observers' beliefs in their own abilities. Social persuasion, in the form of encouragement and positive feedback, can bolster self-efficacy. Physiological and emotional states, such as stress or fatigue, also inform individuals' judgments of their capability.

In educational contexts, teacher self-efficacy has emerged as a critical construct. Teachers with high self-efficacy demonstrate greater resilience in the face of challenges, more persistent effort, and higher levels of teaching innovation (Azila-Gbetteo et al., 2021; Basileo et al., 2024). They are more likely to adopt student centered approaches, including situational and project-based learning, and to persist when implementation proves difficult (Higde et al., 2014; Lekhu, 2016).

For physics teachers in particular, self-efficacy beliefs influence their willingness to engage with abstract concepts, to facilitate laboratory work, and to address student misconceptions (Lin & Luo, 2023). In this study, we assessed teacher self-efficacy through semi-structured interviews two weeks after the training. The interviews focused on teaching competence, transfer of training, resilience, professional identity, and reflective self-evaluation.

Research Aim and Questions

This study examined the effects of a short-term continuous professional development program for physics teachers in the Democratic Republic of Congo. The training focused on two complementary components: the effective use of didactic materials and the implementation of situation-based teaching. The latter, rooted in the work of Lave and Wenger (1991), involved engaging students with authentic problems drawn from their daily experience, an approach shown to foster deeper cognitive engagement and transferable skills (Jonnaert, 2011, 2018).

We assessed the intervention across three cognitive dimensions: conceptual understanding, procedural fluency, and symbolic reasoning. These dimensions capture distinct aspects of physics competence and allow for a nuanced evaluation of where teacher training yields measurable effects.

Specifically, the study addressed the following research questions:

1. Which dimensions of physics learning improve, and which remain unchanged, following a short-term teacher professional development program on didactic materials and situation-based teaching, compared to conventional teaching?
2. How does participation in this professional development program influence physics teachers' self-efficacy and reported classroom practices?
3. What types of errors persist in student responses after the intervention, and what do these errors indicate about the limits of short-term teacher training?

By situating the study in a resource-constrained African context, this research provides evidence on whether short-term, low-cost interventions can meaningfully improve student achievement. The findings have implications for educational policy and practice in similar settings across the continent.

Research Methodology

Design

This study followed a quasiexperimental approach with a nonequivalent control group design. The research was carried out between September and December 2024 in the educational subdivision of MbanzaNgungu I. The study's scope covered ten secondary schools offering a scientific track at the upper secondary level. The theoretical framework, grounded in didactic materials, situational learning, and teacher self-efficacy, informed the design of the intervention and the selection of outcome measures.

Due to administrative constraints imposed by local educational authorities, pre-test data could be collected only in experimental schools. Authorities permitted only one assessment per school to avoid disrupting school schedules. Consequently, the design incorporated

two complementary analytical strategies: a withingroup comparison of pretest and posttest performance in experimental schools, and a between-group comparison of posttest scores only. The convergence of results across both strategies supports the interpretation that observed gains are likely attributable to the intervention.

Five secondary schools were assigned to the experimental group, and five to the control group. Assignment of schools to groups was not random. Instead, allocation was based on two criteria: teacher years of experience (to ensure balance between novice and experienced teachers across groups) and school management type (private versus official schools).

For schools where physics teachers had similar years of experience and the same management type, assignment to experimental or control groups was determined by exhaustive random drawing. This additional step ensured that when no difference in teacher characteristics existed between two schools, chance alone decided group allocation.

This nonrandom assignment is acknowledged as a limitation in the interpretation of findings. However, nonrandomization was deliberately used to avoid a potential bias. If all experienced teachers had been placed in the same group, the intervention's effects could have been confounded with teacher experience. Balancing the groups on years of experience was a methodological safeguard, not a flaw.

Teachers in the experimental group received a threeday training program focused on didactic materials and situationbased teaching. Teachers in the control group continued with conventional teaching practices and received no intervention. All teachers taught the same topic, electric generators and receivers, during the same period under normal classroom conditions. The study included all students and all teachers from the ten authorized schools. No sampling was applied.

Participants

The study was conducted in the educational subdivision of MbanzaNgungu I in the Democratic Republic of Congo. Ten secondary schools offering a scientific track at the upper secondary level participated. Each school had one physics teacher responsible for final-year science classes. All teachers held a five-year university degree (BAC+5), the legally required qualification to teach physics at the secondary level in the DRC. Teachers without formal qualification were excluded under the terms of authorization granted by local authorities. This exclusion limits generalizability, as unqualified teachers form a substantial portion of the teaching workforce in many Congolese schools.

All ten teachers were male. No qualified female physics teacher was available in the study area. Table 1 presents the institutional profile of the ten surveyed schools, including student enrollment per school and group assignment.

Table 1
Institutional Profile of Surveyed Schools

School Code	Number of Students	Assigned Group
School 1	31	Experimental
School 2	35	Experimental
School 3	48	Experimental
School 4	7	Experimental
School 5	3	Experimental
School 6	16	Control
School 7	28	Control
School 8	17	Control
School 9	49	Control
School 10	14	Control

Table 2 shows teacher distribution by group, years of experience, and prior training. Four teachers had less than five years of experience (two experimental, two control). Four teachers had between five and ten years of experience (two in each group). Two teachers had more than ten years of experience (one in each group). All teachers reported prior participation in at least one capacitybuilding training organized by the provincial education inspection service.

Table 2
Teacher Characteristics by Group

Teacher ID	Group	Years of Experience	Prior Training
T1	Experimental	< 5	Yes
T2	Experimental	< 5	Yes
T3	Experimental	5-10	Yes
T4	Experimental	5-10	Yes
T5	Experimental	> 10	Yes
T6	Control	< 5	Yes
T7	Control	< 5	Yes
T8	Control	5-10	Yes
T9	Control	5-10	Yes
T10	Control	> 10	Yes

The postintervention assessment included 248 students, with 124 in each group. The experimental group had 65 female and 59 male students. The control group had 69 female and 55 male students. The study covered all students and all teachers from the ten authorized schools. No sampling was applied. For experimental schools, pretest scores from the previous academic year were available for a different cohort of 116 students taught by the same teachers before the intervention.

Classroom Observations

Classroom observations were conducted in all ten schools before the intervention. Preintervention observations revealed that physics teaching was predominantly theoretical, didactic materials were rarely used, and situationbased teaching was not implemented.

Postintervention observations focused on the five experimental schools. They confirmed that teachers used the fabricated didactic materials (circuit boards, generator models) and implemented situationbased teaching as introduced in the training. Quantitatively, in four out of five experimental schools, at least one didactic material was used during more than 50% of lesson time, indicating a substantial uptake of the trained strategies. However, the frequency and quality of procedural teaching varied across teachers.

No postintervention observations were conducted in control schools, as the research authorization did not permit additional classroom visits. Preintervention observations confirmed that control teachers used conventional lecturebased methods without didactic materials or situational approaches.

These observations are not the focus of this paper but are mentioned here to confirm implementation fidelity.

Teacher Professional Development Intervention

We put together a team to design and run the training. The team had six people: a psychologist, an educator, someone who designs educational materials, a secondary physics inspector, a didactician, and a physicist who coordinated everything. The training covered two main things. First, how to use didactic materials in teaching sequences. Second, how to teach with situations.

The part on didactic materials dealt with what counts as a teaching resource, how to make materials from local and recycled things, and how to bring those resources into the classroom. The teachers made simple circuit boards and recycled generator models to use in their own lessons.

The part on situationbased teaching introduced authentic problem design. It also showed ways to base teaching on what students already experience, and techniques to encourage students to ask questions rather than just listen to a lecture. The training also covered what makes a good situation, how to exploit a situation pedagogically, and how to assess within a situational approach. We added topics on problembased learning and inquirybased learning.

Training was delivered in a blended format combining two inperson days with remote followup during the third day via mobile phone calls and text messaging, as Internet access was not available to all teachers. Teacher learning was assessed through classroom simulations, peer feedback, and posttraining observations during actual teaching. Remediation was provided through targeted coaching to participants who required additional support.

Content and Structure of Lessons for Control and Experimental Groups

Both groups studied the same physics topic, electric generators and receivers, over three weeks. Each group spent six hours on the topic, two hours per week.

Teachers in the control group kept using their usual ways of teaching. They gave teachercentered lectures. The teacher wrote theoretical content on the blackboard, sometimes asked questions to the class, and gave written exercises from the textbook. Nobody used any didactic materials except the blackboard and chalk. No situationbased teaching or inquiry activities. Assessment was limited to endofchapter written tests that focused on declarative knowledge. The same teacher taught all lessons. There was no external help or coaching.

Teachers in the experimental group did the threeday training first. After that, they structured their lessons around situationbased teaching. Each lesson started with a real problem from the students' daily lives. For example, why do the lamps in a house stop working? The teachers used the didactic materials they had made during the training, simple circuit boards and recycled generator models, so students could touch and test things. Lessons included inquiry activities, group discussions, and problemsolving tasks. Formative assessment was used throughout, not just at the end. The focus was on what students could do, not just on memorized facts. The same teachers taught all lessons, but we supported them with posttraining observations and some coaching when needed.

Table 3 shows the differences between the two groups: time spent on the topic, lesson structure, use of didactic materials, teaching approach, and how assessment was done.

Table 3

Comparison of Educational Contexts for Control and Experimental Groups

Feature	Control Group	Experimental Group
Topic	Electric generators and receivers	Electric generators and receivers
Total Teaching time	6 hours (2 hours/week over 3 weeks)	6 hours (2 hours/week over 3 weeks)
Lesson structure	Teachercentered lectures	Situationbased, inquirydriven
Didactic materials	Blackboard and chalk only	Fabricated circuit boards, recycled generator models, diagrams
Teaching approach	Objectivebased, theoretical	Situationbased, studentcentered
Feature	Control Group	Experimental Group
Topic	Electric generators and receivers	Electric generators and receivers

Assessment Instrument

A standardized test developed by the expert team assessed student learning across three dimensions of physics understanding.

- *Conceptual dimension*: ability to identify and connect fundamental scientific principles and relationships.
- *Procedural dimension*: capacity to apply methods, solve problems, and execute standard procedures.
- *Symbolic dimension*: fluency in interpreting and manipulating scientific representations, including formulas, diagrams, and graphs.

The test contained ten items. Three items targeted conceptual understanding, three targeted procedural skills, and four targeted symbolic reasoning. Items were distributed across Bloom's taxonomy levels from basic understanding (Level 2) to evaluation (Level 6).

Table 4 presents the classification of test items according to dimension, Bloom's taxonomy level, and evaluative purpose.

Table 4
Analytical Grid of Assessment Items

Item	Dimension	Bloom's Taxonomy Level	Evaluative Purpose
Q1	Conceptual	Understand (Level 2)	Assess definitional clarity and categorical logic
Q2	Conceptual	Understand (Level 2)	Evaluate knowledge of generator properties
Q3	Conceptual	Analyze (Level 4)	Test causal reasoning in basic circuit logic
Q4	Procedural	Apply (Level 3)	Assess ability to define and contextualize
Q5	Procedural	Analyze (Level 4)	Evaluate categorization and applied reasoning
Q6	Procedural	Apply (Level 3)	Test symbol interpretation and component identification
Q7	Symbolic	Apply (Level 3)	Assess symbolic manipulation and circuit analysis
Q8	Symbolic	Analyze (Level 4)	Evaluate symbolic modeling and energy analysis
Q9	Symbolic	Apply (Level 3)	Test algebraic manipulation and Ohm's Law application
Q10	Symbolic	Evaluate (Level 6)	Assess procedural logic and symbolic planning

Instrument Validation

The test was preadministered to a sample of students outside the target population to evaluate psychometric properties. Item difficulty and discrimination indices were calculated using Classical Test Theory procedures (Kline, 2005). Items were retained if they met two criteria: a difficulty index between .30 and .80, and a discrimination index of at least .25 (Ding & Beichner, 2009; Ukofia & Essen, 2021).

Item Q10 (Bloom's Level 6, evaluation) showed a discrimination index of .12, below the conventional threshold. The item was retained because it assessed higherorder reasoning not captured by other items. A sensitivity analysis excluding Q10 was conducted. For the symbolic dimension without Q10, the difficulty index was .27, and the discrimination index improved to .42. The main findings remained unchanged when Q10 was excluded.

Reliability was assessed using Cronbach's alpha. The global Cronbach's alpha for the full 10item test was .84, reflecting the combined variance across all items. Lower alpha values for the procedural dimension ($\alpha = .71$) and conceptual dimension ($\alpha = .78$) are expected, given the small number of items in each subscale (three items each). The symbolic dimension (four items) yielded $\alpha = .82$. The moderate correlations among dimensions (consistent with the nature of physics learning, where conceptual understanding supports symbolic manipulation) contribute to the higher global alpha without threatening the distinctiveness of the three dimensions.

Interrater reliability for the openended questions (Q4, Q5, Q8, Q10) was established by having two independent raters score a randomly selected subset of 30 responses. Cohen's kappa was $\kappa = .79$, indicating substantial agreement. Disagreements were resolved through discussion.

A linguistic clarity review was conducted by a language expert and validated by the expert panel to ensure contextual appropriateness for Congolese secondary students.

Data Collection

Posttest data were collected from all 248 students in the ten participating schools. The assessment was administered on the same day across all schools under the supervision of trained observers who ensured consistency in administration conditions. Teachers from both groups were not present during testing. Tests were graded by independent experts and trained personnel unaware of students' group affiliation. Responses were coded, anonymized, and entered into a database for statistical analysis.

For experimental schools, pretest scores from the previous academic year were available for a different cohort of 116 students taught by the same teachers before the intervention.

Teacher SelfEfficacy Assessment

We interviewed the five teachers from the experimental group about two weeks after the training. The interviews were semistructured. We had ten openended questions, grouped into five themes based on Bandura's model: teaching competence, transfer of training, resilience in teaching situations, professional identity, and reflective selfevaluation. The interviews were done in French. We recorded them with each teacher's permission and transcribed everything word for word.

For the analysis, we used thematic analysis as described by Braun and Clarke (2006). That means we went through six steps: we read through the transcripts to get familiar with the data, generated initial codes, looked for themes, reviewed them, defined them clearly, and finally wrote up the report.

Ethical Considerations

The study followed standard ethical protocols for educational research. Permission was granted by the higher educational authorities of the MbanzaNgungu subdivision. School principals provided institutional consent. All participating teachers gave written informed consent. For student participants, passive parental consent was obtained following local norms. Parents were informed of the study and given the opportunity to withdraw their child. All data were anonymized before analysis. Participants are not identifiable in any report or publication.

Data Analysis

All statistical analyses were conducted using SPSS (version 23). Normality of distributions was assessed using the KolmogorovSmirnov test. For between group comparisons of posttest scores, independent samples *t* tests were used when normality assumptions were met. MannWhitney *U* tests were employed as nonparametric alternatives.

Because students were nested within schools and teachers (10 schools, 10 teachers), the assumption of independence of observations was violated. To assess whether the nesting of students within schools affected the results, sensitivity analyses were conducted using robust standard errors clustered at the school level and using schoolmean aggregated scores. These sensitivity analyses confirmed the pattern of statistical significance obtained with the conventional tests (see Results). For simplicity, results from conventional tests (independent samples *t* tests and MannWhitney *U* tests) are presented in the tables.

For withingroup comparisons in experimental schools (pretest cohort, $n = 116$, versus posttest cohort, $n = 124$), independent samples *t* tests were used because the two cohorts comprised different individuals. Effect sizes (Cohen's *d*) were calculated for all comparisons (Cohen, 1988).

Because the school-level data were not normally distributed, heterogeneity between schools was examined using a Kruskal-Wallis test, followed by Dunn's post-hoc test with Bonferroni correction. Results are interpreted conservatively given the small number of schools ($n = 10$).

Research Results

Descriptive Results and Group Comparisons

Table 5 presents itemlevel means and standard deviations for the experimental and control groups on the posttest. Standard deviations are reported separately for each group for each of the ten items.

Table 5
ItemLevel Descriptive Statistics by Group

Dimension	Item	Experimental group			Control group		
		<i>M</i>	<i>SD</i>	Dimension mean	<i>M</i>	<i>SD</i>	Dimension mean
Conceptual	Q1	0.85	0.48	0.77	0.62	0.50	0.63
	Q2	0.92	0.26		0.74	0.40	
	Q3	0.78	0.43		0.55	0.50	
Procedural	Q4	0.68	0.30	0.42	0.60	0.30	0.45
	Q5	0.55	0.26		0.52	0.27	
	Q6	0.48	0.35		0.42	0.50	
Symbolic	Q7	0.52	0.31	0.32	0.28	0.23	0.15
	Q8	0.38	0.27		0.23	0.20	
	Q9	0.31	0.35		0.15	0.20	
	Q10	0.18	0.16		0.08	0.09	

Note. $n = 124$ for both experimental and control groups. SD: Standard deviation.

Normality Testing

Prior to conducting group comparisons, normality was assessed using the KolmogorovSmirnov test. Scores on the conceptual dimension departed significantly from normality in both groups ($p < .001$). Procedural dimension scores also showed nonnormal distributions ($p = .014$ for experimental, $p = .008$ for control). Symbolic dimension scores and total scores were normally distributed in both groups ($p > .05$). Given these results, between-group comparisons were conducted using MannWhitney U tests for conceptual and procedural dimensions, and independent samples t tests for symbolic dimension and total score. For consistency, t test results are also reported with Welch correction where homogeneity of variance assumptions were violated.

BetweenGroup Comparisons

Table 6 presents the results of between-group comparisons. The experimental group significantly outperformed the control group on the conceptual dimension ($U = 9556$, $p = .004$), with a mean difference of 0.14. The effect size for this difference, calculated using Cohen's d from the means and pooled standard deviation, was 0.49, indicating a small to moderate effect.

On the procedural dimension, no significant difference emerged between groups ($U = 6990$, $p = .215$). The control group mean (0.45) slightly exceeded the experimental group mean (0.42), but this difference was not statistically reliable. The effect size ($d = -0.16$) was negligible.

The symbolic dimension revealed the largest group difference. Experimental group students ($M = 0.32$, $SD = 0.12$) substantially outperformed control group students ($M = 0.15$,

$SD = 0.09$), a difference that was highly significant ($t(246) = 12.48, p < .001$). The effect size was large ($d = 1.58$), indicating that the average student in the experimental group scored more than one and a half standard deviations above the average control group student.

Total scores followed a similar pattern. Experimental group students ($M = 0.49, SD = 0.14$) scored significantly higher than control group students ($M = 0.38, SD = 0.12$), with $t(246) = 6.54, p < .001$, and a moderate to large effect size ($d = 0.83$).

Table 6
Between-Group Comparisons of Post-Test Scores

Dimension	Experimental Mean (SD)	Control Mean (SD)	Mean Diff	Test Statistic	p	Cohen's d
Conceptual	0.77 (0.18)	0.63 (0.21)	0.14	$U = 9556$	.004	0.49
Procedural	0.42 (0.15)	0.45 (0.16)	-0.03	$U = 6990$	.215	-0.16
Symbolic	0.32 (0.12)	0.15 (0.09)	0.17	$t = 12.48$	< .001	1.58
Total	0.49 (0.14)	0.38 (0.12)	0.11	$t = 6.54$	< .001	0.83

Note. For symbolic dimension and total score, degrees of freedom = 246. For conceptual and procedural dimensions, U values are reported. SD: Standard deviation.

As shown in Table 7, the pattern of statistical significance remained consistent across all three analytical approaches. The conceptual dimension remained significant (all $p < .05$), the procedural dimension remained nonsignificant (all $p > .05$), and both the symbolic dimension and total score remained significant (all $p < .01$). These results confirm that the main findings are not artifacts of the nested data structure or the choice of analytical method.

Table 7
Sensitivity Analysis: Comparison of pvalues Across Analytical Approaches

Dimension	Conventional test (p)	Robust SE clustered by school (p)	Schoolmean aggregated (p)
Conceptual	.004	.011	.024
Procedural	.215	.308	.412
Symbolic	< .001	< .001	.003
Total	< .001	< .001	.002

Note. Conventional tests: independent samples t -test for symbolic and total scores; MannWhitney U test for conceptual and procedural dimensions (see Table 6). Robust standard errors were clustered at the school level ($n = 10$ schools). Schoolmean aggregated scores were compared using independent samples t -tests ($n = 10$ schools). SE: Standard error.

WithinGroup Comparisons for Experimental Schools

For the five experimental schools, pretest scores from the previous academic year were available for a different cohort of 116 students taught by the same teachers before the intervention. Table 8 presents a comparison between the pretest and the posttest cohorts.

Significant gains appeared across all dimensions. Conceptual understanding increased from 0.52 to 0.77, $t(238) = 10.24, p < .001, d = 1.32$. Procedural skills improved modestly from 0.38 to 0.42, $t(238) = 2.18, p = .030, d = 0.28$. Symbolic reasoning showed substantial improvement from 0.18 to 0.32, $t(238) = 9.76, p < .001, d = 1.26$. Total scores increased from 0.34 to 0.49, $t(238) = 8.85, p < .001, d = 1.14$.

It is important to note that the following withingroup comparisons (pretest vs posttest in experimental schools) show changes over time, not causal effects of the intervention. These results complement the between-group comparisons reported above.

Table 8
Within-Group Comparisons for Experimental Schools: Pre-Test versus Post-Test

Dimension	Pre-Test Mean (SD) (n=116)	Post-Test Mean (SD) (n=124)	Mean Gain	t	df	p	Cohen's d
Conceptual	0.52 (0.20)	0.77 (0.18)	0.25	10.24	238	< .001	1.32
Procedural	0.38 (0.14)	0.42 (0.15)	0.04	2.18	238	.030	0.28
Symbolic	0.18 (0.10)	0.32 (0.12)	0.14	9.76	238	< .001	1.26
Total	0.34 (0.13)	0.49 (0.14)	0.15	8.85	238	< .001	1.14

Note. SD: Standard deviation.

Item Difficulty and Discrimination Indices

Table 9 reports item difficulty and discrimination indices calculated from the full posttest sample ($n = 248$). Difficulty indices ranged from .13 (Q10) to .87 (Q2), indicating that the test captured a broad spectrum of student ability. Discrimination indices exceeded the conventional threshold of .25 for all items except Q10, which showed poor discrimination (.12). This item, corresponding to Bloom's evaluation level, proved challenging for students regardless of overall performance level.

At the dimension level, conceptual items demonstrated appropriate difficulty (.70) and strong discrimination (.59). Procedural items were more difficult (.43) with acceptable discrimination (.28). Symbolic items were the most challenging (.24) but maintained adequate discrimination (.34) when Q10 was included. Excluding Q10 raised the symbolic dimension discrimination to .42.

Table 9
Item Difficulty and Discrimination Indices

Dimensions	Items	Difficulty indices		Discrimination indices	
		Item index	Dimension index	Item index	Dimension index
Conceptual	Q1	.60	.70	.76	.59
	Q2	.87		.36	
	Q3	.65		.66	
Procedural	Q4	.72	.43	.28	.28
	Q5	.29		.26	
	Q6	.29		.31	
Symbolic	Q7	.31	.23	.46	.34
	Q8	.30		.39	
	Q9	.20		.40	
	Q10	.13		.12	

School Level Heterogeneity

Nonparametric analyses were conducted due to violation of normality assumptions. A KruskalWallis test revealed significant differences among the ten schools on all dimensions: conceptual ($H(9) = 72.542, p < .001$), procedural ($H(9) = 60.582, p < .001$), symbolic ($H(9) = 138.608, p < .001$), and total score ($H(9) = 101.456, p < .001$). Post hoc pairwise comparisons

using Dunn's test with Bonferroni correction identified specific patterns of school performance. Lower mean ranks indicate better performance (Figure 2).

On the conceptual dimension, experimental School 2 (Mean Rank = 70.7_b) significantly outperformed all other schools. Experimental Schools 3, 6, 7, and control School 9 (135.0_a) formed an intermediate tier, while control School 8 (216.6_c) performed the worst.

On the procedural dimension, experimental School 5 (42.0_{ade}) and control School 6 (49.2_{be}) achieved the lowest mean ranks, followed closely by control School 7 (73.8_{bde}). Control School 8 again showed the poorest performance (205.5_c).

On the symbolic dimension, the largest performance gap emerged. Experimental Schools 3 (48.1_c) and 2 (80.0_{ae}) outperformed all others, followed by control School 7 (98.0_{abe}). Control School 8 (226.8_c) was weakest, with experimental School 5 also performing poorly (187.5_{abcd}).

For total score, experimental Schools 2 (76.3_b) and 3 (79.8_b) ranked best, together with control Schools 7 (92.7_{bd}) and 6 (105.4_{abe}). Control School 8 (234.9_c) remained the lowest performer.

In summary, experimental schools consistently outperformed control schools on conceptual and symbolic dimensions, with Schools 2 and 3 leading. On procedural skills, one experimental school (School 5) excelled alongside control Schools 6 and 7. Control School 8 was the weakest across all dimensions.

Visual Representation of Student Performance

Figure 1 presents radar charts comparing student competency profiles across the three dimensions. The experimental group's polygon nearly encompasses the control group's polygon, visually confirming superior performance across all dimensions.

Figure 1
Radar Chart of Dimension Performance

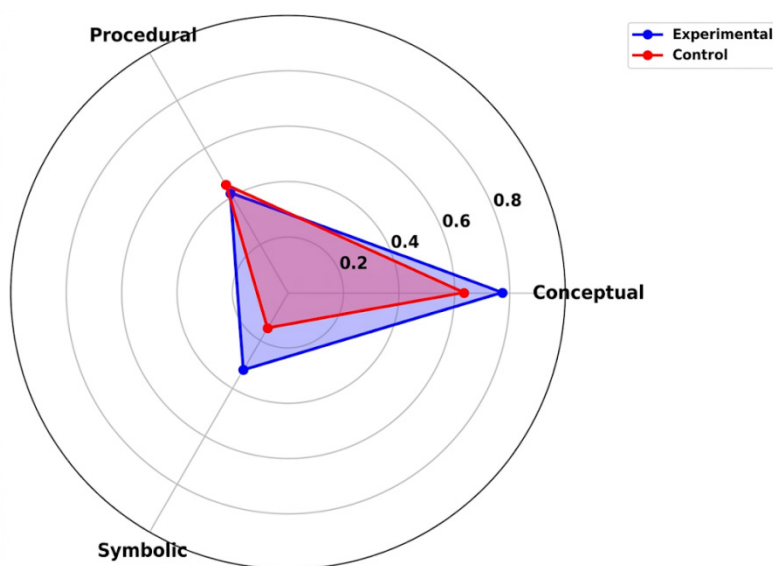
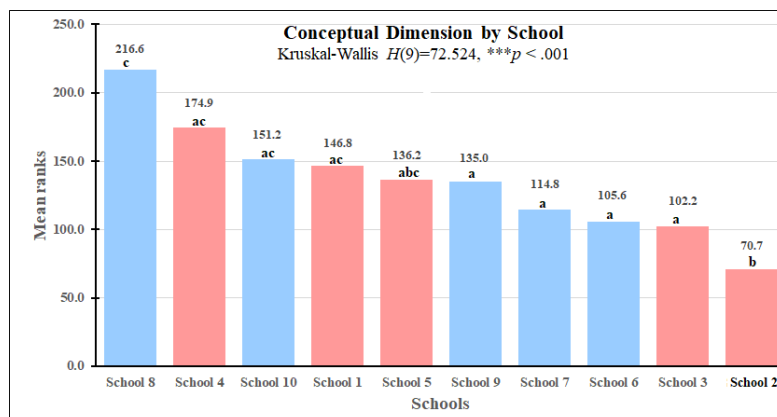


Figure 2 presents schoollevel mean ranks for (a) conceptual, (b) procedural, (c) symbolic, and (d) total score dimensions. Red bars indicate experimental schools, blue bars indicate

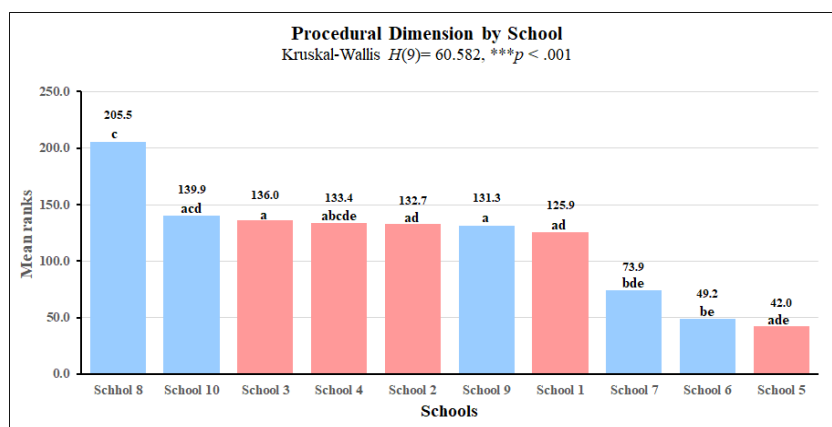
control schools. These plots reveal substantial heterogeneity among schools, particularly in the symbolic dimension.

Figure 2

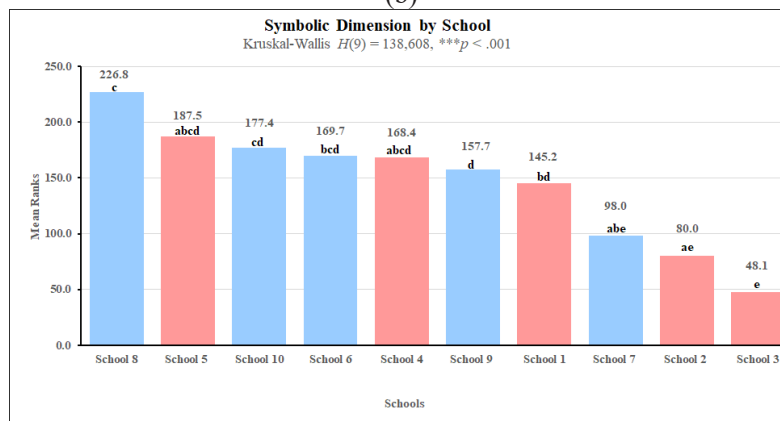
Mean Ranks and Homogeneous Subsets for Conceptual, Procedural, Symbolic, and Total Score Dimensions across 10 Schools (Dunn's Test with Bonferroni Adjustment)



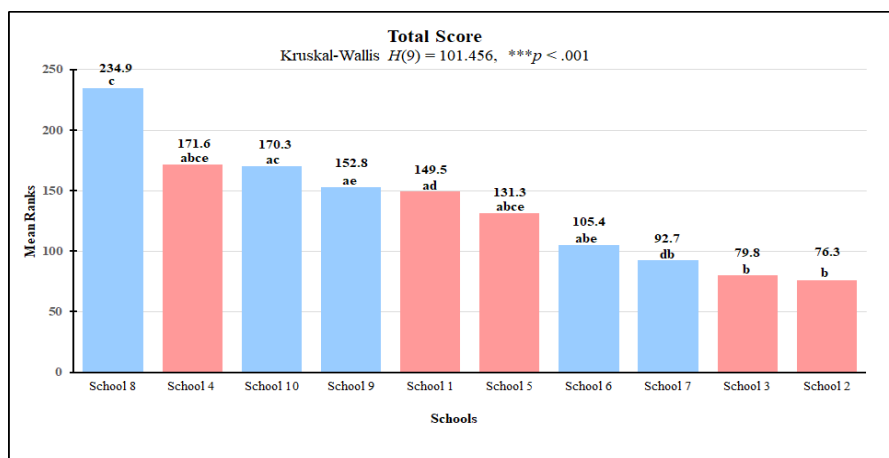
(a)



(b)



(c)



(d)

Note. Values sharing the same subscript letter (a, b, c, d, e) do not differ significantly at $p < .05$ after Bonferroni correction.

Error Analysis

Table 10 summarizes the nature and persistence of errors observed in student responses. Errors fell into three categories: those corrected in the experimental group (present in control but absent or substantially reduced in experimental), those persisting in both groups, and those for which evidence was inconclusive.

Conceptual errors involving confusion between receivers and generators (Q1), misidentification of generator properties (Q2), and misunderstanding of open versus closed circuits (Q3) were prevalent in the control group but largely absent in the experimental group. Similarly, incomplete definitions and examples (Q4) were corrected following the intervention.

Errors that persisted despite the intervention included confusion about energy types and applications (Q5), misreading of symbols and current direction (Q6), ignoring internal resistance in calculations (Q7), misuse of Ohm's law and unit conversion (Q9), illogical problemsolving sequences (Q10a), and omission of essential tools (Q10b). These errors appeared with comparable frequency in both groups.

Item Q8 (misconceptions about EMF, voltage, and efficiency) yielded inconclusive results due to incomplete responses in the experimental group. Many students left this item blank or provided partial answers that could not be reliably coded.

Table 10

Summary of Learner Errors, Their Persistence, and Illustrative Examples

Item	Nature of Error	Illustrative Student Error	Observed in Control	Observed in Experimental	Status
Q1	Receiver vs. generator confusion	Selecting the generator definition for a receiver.	Yes	No	Corrected
Q2	Misidentifying generator properties	Choosing "polarity and internal resistance" instead of EMF.	Yes	No	Corrected
Q3	Open vs. closed circuit confusion	Marking "True" for "if a lamp fails, the circuit must be closed."	Yes	No	Corrected
Q4	Incomplete definition/examples	Vague definition ("It produces current") with a poor example ("A battery").	Yes	No	Corrected
Q5	Confusion on energy types	Listing "electrical energy" as input for a generator.	Yes	Yes	Persistent
Q6	Misreading symbols/current	Selecting a battery symbol to represent a receiver.	Yes	Yes	Persistent
Q7	Ignoring internal resistance	Calculating current using only the external resistor ($I = 10/4 = 2.5 \text{ A}$).	Yes	Yes	Persistent
Q8	EMF/voltage misconceptions	Confusing terminal voltage with EMF to find internal resistance.	Yes	Incomplete	Inconclusive
Q9	Ohm's law/unit conversion errors	Using 238 mA as 238 A in a calculation.	Yes	Yes	Persistent
Q10a	Illogical problem-solving sequence	Suggesting replacing the bulb before checking for power.	Yes	Yes	Persistent
Q10b	Omitting essential tools	Listing a new bulb but forgetting a multimeter for diagnosis.	Yes	Yes	Persistent

Teacher Self-Efficacy: Qualitative Findings

Four patterns emerged from the interviews, though not all teachers expressed the same views.

Teaching confidence. Four teachers said they felt less anxious about teaching topics they previously avoided. One teacher explained: "Before, I would skip some parts. I was not sure how to explain them. Now I try anyway. I prepare more before class." Another teacher added: "I still have trouble with some formulas, but I am not afraid to stand in front and try." A third teacher said: "The training helped me see that I do not need to know everything. I can learn with the students sometimes." One teacher, however, expressed continued hesitation: "I still do not feel confident with the symbolic part. The training gave me ideas, but in class it is different. The students ask questions I did not expect."

Changes in classroom practice. All five teachers reported changing at least one aspect of their teaching. Two teachers said they started using local examples more often. One said: "I asked students to bring old batteries and small bulbs from home. We built simple circuits. They liked it. I will do this again." Another teacher described a change in pacing: "Before, I would answer my own question if no one spoke. Now I wait longer. Sometimes I wait too long, but I am learning." A third teacher tried the situation about lamps that do not light up. He said: "It worked well, but it took more time than I expected. I had to cut some exercises. Next time I will plan better." Two teachers mentioned that not all changes worked. One said: "I tried group work once, but the class became noisy. I went back to lecture. Maybe I will try again later."

Resilience and problemsolving. Three teachers reported feeling better equipped to handle student confusion. One said: “When students do not understand, I do not get angry anymore. I ask another student to explain in their own words. Sometimes it helps. Sometimes it does not.” Another teacher noted: “I still struggle with students who mix up voltage and current. I have tried three different explanations. Nothing works perfectly yet.” A third teacher said: “Before the training, I would just repeat the same sentence louder. Now I try to draw a picture or use an example from the house. It works better.” The two remaining teachers said they still felt frustrated when students did not understand. One of them said: “I know I should be patient, but when the same student makes the same error for the third time, I lose my temper. I am working on it.”

Professional identity. Two teachers explicitly described a shift in how they saw their role. One stated: “I used to think my job was to finish the program. Now I think my job is to make sure they understand. If they do not understand, I have not finished.” Another teacher said: “I am still the boss in the classroom, but I let them talk more. It is a small change, but it is a change.” The other three teachers did not express a clear shift in professional identity. When asked about their role, they focused on techniques rather than identity. One said: “I am a physics teacher. That has not changed. What changed is that I have more materials to use.”

We saw differences between the five teachers. Four felt more confident. One was still unsure. All five changed something in their teaching, but not every change worked well. Three teachers found better ways to help confused students. Two still got frustrated easily. Only two described a clear shift in their professional identity.

The quantitative results showed no improvement in procedural skills. Maybe that is because the teachers lacked good strategies for teaching procedures. They also did not know how to handle unexpected student questions.

Discussion

Interpretation of Main Findings

Conceptual and symbolic gains. Students from the trained teachers scored higher than controls in both conceptual and symbolic dimensions. The effect sizes were moderate to large. In the experimental schools only, we also compared two different cohorts taught by the same teachers before and after the training. Those comparisons showed large gains as well (conceptual $d = 1.32$, symbolic $d = 1.26$). Taken together, these results suggest that even a threeday training can improve student performance in these two areas. We did not expect such a clear difference for symbolic reasoning. The fabricated materials, simple circuit boards, and recycled generator models may have helped. Students could see what the diagrams represented. That tangibility probably matters. Our finding aligns with what McLoughlin et al. (2024) and others have argued: manipulating physical objects supports the interpretation of abstract symbols.

The conceptual gains were less surprising. When teaching starts from authentic problems, students build links between formal knowledge and their daily lives. That is exactly what situated learning predicts (Jonnaert, 2011, 2018). Our training emphasized problems like failing lamps in a house. Teachers who used such scenarios reported that students engaged more than usual.

Procedural skills. Here, the results were different. We found no significant difference between experimental and control students on procedural items ($p = .215$). Within the experimental schools, there was a small gain from pretest to posttest ($d = 0.28$, $p = .030$), but that gain was much smaller than for the other two dimensions. The between-group comparison, which is less sensitive to cohort differences, showed no improvement at all. Our interpretation is that the intervention did not meaningfully change procedural skills.

Procedural skills in physics depend heavily on mathematical fluency: unit conversion, algebra, and graph interpretation. Students in both groups made the same kind of errors on these tasks, even when they clearly understood the underlying physics concepts. This pattern matches what others have found. Badmus and Jita (2024) reported that South African students who struggle in physics usually have weak math skills. Tong et al. (2025) showed that algebra ability predicts physics problemsolving regardless of teaching quality. The errors we saw, misapplying Ohm's law, incorrect unit conversions, and illogical solution sequences, fit exactly with those findings.

Teacher selfefficacy and classroom practice. In the interviews, most trained teachers said they felt more confident. Some changed their routines. A few even talked about their role as a teacher differently. But not everyone changed the same way. One teacher remained hesitant. Two others said they still felt frustrated when students did not understand. Training alone is clearly not enough. A teacher's prior beliefs and years of experience probably shape how much they adopt new strategies. Bandura (1997) would say that people interpret mastery experiences differently, and we saw that variability in our small sample.

Why did procedural skills not improve? The interviews gave us one clue. Several teachers admitted they lacked specific strategies for teaching procedures. They did not know how to respond when students asked unexpected questions about calculations or unit conversions. Even when they felt more confident overall, they had not developed methods for scaffolding procedural learning. This suggests that procedural fluency may require longer interventions or collaboration with mathematics teachers, not just physicsfocused training.

Schoollevel heterogeneity. After the intervention, schools still differed significantly from each other. Two experimental schools, Schools 2 and 3, performed well on all dimensions. One experimental school, School 4, performed below the others. And one control school, School 7, scored high on several dimensions. This variation matters. All teachers in the study, including controls, had attended at least one prior training organized by the provincial education division. Some control teachers may therefore have improved their teaching before our study started. Others may simply be better teachers regardless of training, or they may have stronger students. Our data cannot test these possibilities, but they should be investigated in future research.

Connection to Existing Literature

Other studies have shown that professional development can help teachers in lowresource schools (Babalola & Ojobalo, 2022; Fazio & Logman, 2024). Our study adds that even three days of training can produce measurable gains in conceptual and symbolic learning.

The null effect on procedural skills contributes to a growing body of work on mathematics as a bottleneck. Badmus and Jita (2024) and Tong et al. (2025) both pointed to weak math skills as a key limit to physics learning. Our study shows that this limit persists even when teachers receive training in didactic materials and situationbased teaching. Procedural skills do not improve automatically. This suggests that improving them may require explicit collaboration between physics and mathematics teachers, or interventions that directly target mathematical reasoning within physics problems.

Our interviews also connect to Bandura's (1997) theory. Teachers who successfully tried new strategies reported more confidence. Those who observed peers during training described adopting similar techniques. Yet not all teachers changed in the same way. That variability is exactly what Bandura would expect: individuals interpret similar experiences differently.

Limitations

We need to be honest about what this study cannot claim.

Causal inference. The absence of a pretest for the control group was not our choice. Local authorities allowed only one assessment per school to avoid disrupting schedules. The same constraint forced us to use different cohorts for pretest and posttest comparisons in experimental schools. These are real limitations. We cannot make strong causal claims. That said, two different analytical strategies converged on the same pattern, which makes us more confident that the intervention had some effect. Still, unmeasured differences between schools may contribute to what we observed.

Different cohorts for pretest and posttest. Because we could not test the same students before and after in the experimental schools, the gains we report could reflect differences in cohort ability, changes in the curriculum, or other historical factors. We cannot isolate the intervention as the only cause.

Clustering. Students were nested in ten schools taught by ten teachers. We did not have enough statistical power for multilevel modeling. We used robust standard errors clustered at the school level, but that is only a partial fix.

Item Q10. This item had poor discrimination (.12). We kept it only because it assessed higherorder reasoning (Bloom's Level 6) that no other item captured. When we excluded Q10 from the sensitivity analyses, the main findings did not change. But the item should be revised or replaced in future studies.

Generalizability. Our sample did not include teachers without formal qualifications. In many Congolese schools, such teachers make up a large portion of the workforce. Our findings may not apply to their classrooms.

Combined intervention. The training had two components: didactic materials and situationbased teaching. Our design does not allow us to separate their effects. Possibly one component drove most of the gains while the other contributed little, or they worked together synergistically. We cannot tell.

Conclusions and Implications

We trained five physics teachers in the Democratic Republic of Congo during a threeday program on didactic materials and situationbased teaching. The other five teachers in the study continued with their usual practices. Students taught by the trained teachers scored higher than students in the control group on conceptual questions ($d = 0.49$) and on symbolic reasoning ($d = 1.58$). We cannot yet tell whether the didactic materials or the situationbased teaching made the difference. Procedural skills did not improve. Students in both groups kept making the same mistakes: wrong unit conversions, poor algebra, and difficulty reading graphs. The trained teachers reported more confidence, but not all of them changed their classroom routines in the same way. Shortterm interventions can help in specific areas, but the effect is partial.

Even in resourceconstrained contexts, shortterm training can strengthen conceptual and symbolic learning. Educational authorities need not wait for ideal conditions to start supporting teachers. Locally fabricated didactic materials and situationbased teaching proved effective in making abstract content more accessible. Procedural skills, however, will require changes beyond what shortterm training can offer. The persistence of algebraic and unit conversion errors indicates that mathematical fluency is a critical bottleneck. Collaboration between physics and mathematics teachers, including joint lesson planning, may be necessary to address this challenge. Attention to scientific language also matters. The reduction of lexical errors in the experimental group shows that explicit vocabulary work can improve students' ability to articulate scientific ideas. Language should be treated as a legitimate teaching target in physics classrooms.

For policymakers, the intervention required only three days and used locally fabricated materials, which makes it feasible to scale even in poorly resourced districts. Shortterm, lowcost professional development modules should be integrated into existing inservice training systems. Improving procedural skills will require changes beyond physics teacher training.

Future research needs more robust designs. Randomized assignment and pretests for all groups would strengthen causal inference, provided that local school authorities give their permission. A factorial design would help, but it requires more schools than we had access to. Longitudinal studies following the same students over time would show whether the gains we observed persist or disappear after a few months. We also suspect that mathematical proficiency plays a large role, but we did not measure it directly. Future studies should include such measures to understand how math skills interact with physics teaching. In the Democratic Republic of Congo, the vast majority of schools employ unqualified teachers to deliver physics teaching. Our sample excluded this population. Research specifically targeting unqualified teachers is therefore necessary before concluding that shortterm training generalizes to all teachers.

More broadly, physics education across SubSaharan Africa faces substantial challenges: underqualified teachers, inadequate materials, overcrowded classrooms, and curricula disconnected from students' lives. These systemic issues are not easily resolved. Still, even modest interventions can help. We saw the clearest gains in conceptual and symbolic domains. This suggests that we need longer interventions or collaboration with mathematics teachers. Improvement does not require unlimited resources, but it does require sustained attention to what teachers need to know, how they can teach effectively, and how their beliefs about their own capacity shape classroom practice. Broader systemic reforms are also needed, including better support for mathematics learning alongside physics.

Declaration of Interest

The authors declare no competing interest.

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Appendix

Appendix A: Post-Training Interview Guide for Assessing Teacher Self-Efficacy

1. Self-Perceived Competence
 - 1.1. After the training, how confident do you feel in applying the new teaching strategies in your physics classes?
 - 1.2. Can you describe a moment when you felt particularly effective in teaching a concept using the new approach?
2. Real-World Transfer
 - 2.1. What changes have you made in your classroom practices since the training?
 - 2.2. Have you encountered any difficulties in implementing what you learned? How did you respond to them?
3. Educational Resilience and Adaptation
 - 3.1. In challenging teaching situations, do you feel better equipped to manage student engagement or misconceptions?
 - 3.2. What resources or support would help you feel even more confident in applying these methods?
4. Professional Self-Image
 - 4.1. Has the training changed the way you see yourself as a physics teacher?
 - 4.2. Do you feel more capable of innovating or adapting your teaching to different student needs?
5. Critical Self-Evaluation
 - 5.1. If you had to evaluate your own growth since the training, what would you highlight?
 - 5.2. What advice would you give to a colleague who is about to follow the same training?

Appendix B: Administered Student Assessment Questions

Question 1: Which of the following best defines an electrical receiver?

- [a]. A device that consumes mechanical energy to operate.
- [b]. A device that converts mechanical energy into electrical energy.
- [c]. A device that facilitates the flow of electric current in a circuit.
- [d]. A device that consumes electrical energy to perform a function.
- [e]. A device that transforms any form of energy into electrical energy.

Question 2: Which pair of characteristics most accurately describes an ideal electrical generator?

- [a]. Polarity and internal resistance.
- [b]. Electromotive force and internal resistance.
- [c]. Electrical energy and electromotive force.
- [d]. Counter-electromotive force and internal resistance.
- [e]. Electromotive force and counter-electromotive force.

Question 3: True or False: If a lamp fails to illuminate in an electric circuit, the circuit must be closed.

- ☐ True.
- ☐ False.

Question 4: Define the concept of an electrical generator and provide one real-world example illustrating its application in daily life.

Question 5: Complete the following table by identifying the type of energy transformed and two practical applications for each component:

Component	Energy Transformed	Applications (2)
Generator		
Receiver		

Question 6: Select the diagram that correctly represents an electrical receiver:

- [a]. Symbol for a generator.
- [b]. Symbol for a capacitor.
- [c]. Symbol for a battery.
- [d]. Symbol for a resistor.
- [e]. Symbol for an open switch.

Question 7: A battery has an electromotive force of 10 V and an internal resistance of . It is connected to a resistor. Calculate:

- [a]. The current flowing through the circuit.
- [b]. The voltage drop across the internal resistance.
- [c]. The voltage drop across the resistor.
- [d]. The terminal voltage of the battery.

Question 8: A generator with an electromotive force of 24 V supplies a circuit with a total resistance of . When the circuit is closed, the terminal voltage drops to 20 V. Determine:

- [a]. The internal resistance of the generator.
- [b]. The efficiency (percentage yield) of the generator.

Question 9: Three receivers (a resistor, a lamp, and a motor) are connected in series. The current in the circuit is 238 mA. The voltage drops across the components are:

- [a]. Resistor: 3.15 V
- [b]. Lamp: 2.37 V
- [c]. Motor: 6.43 V

Calculate the resistance value of the resistor.

Question 10: A student notices that the lamps in his house no longer light up, despite the switches being correctly positioned. During a physics class, he presents the issue to his teacher, who invites the class to propose a solution.

- [a]. Outline the sequential steps required to diagnose and resolve the problem.
- [b]. List the materials and tools necessary for the intervention.

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