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Preliminary results from a hands-on STEM teacher training tracer study in Ghana (Evaluation)

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Abstract

Improving science teaching in low-resource contexts remains a major challenge for advancing STEM education and student engagement. Hands-on and inquiry-based instruction are widely recognized as effective, however they remain novel in many parts of the African continent. Professional development efforts to equip teachers with these pedagogies should be evaluated to determine whether participants sustain learned practices over time.

Practical Education Network (PEN), a nonprofit organization based in Ghana, operates on a theory of change in which providing African teachers with practical, low-cost materials for hands-on science instruction strengthens confidence, increases interactive pedagogy, and improves student engagement and achievement. Training in contextually relevant, resource-light experiments is expected to promote sustained classroom use. A tracer study approach follows up with teachers who previously participated in PEN's training program. It quantitatively measures the level of continued implementation of hands-on methods and determines the role of teacher motivation, self-efficacy, and perceived support in sustaining practice.

Survey data were collected from 75 science teachers across six regions of Ghana. Measures captured implementation frequency, perceived support, and motivational constructs. All scales demonstrated acceptable to excellent reliability (α = 0.70–0.99). Most teachers reported continued use of hands-on activities, with 63% still using the PEN teacher resource manual. Teachers also reported high engagement with PEN and moderate to strong peer and school support.

Regression analyses showed that peer and school-based support significantly predicted teacher motivation, whereas neither organizational nor community support predicted implementation frequency. This suggests that strengthening school-based support may be more critical for sustaining teacher motivation than additional organizational follow-up. Further research incorporating classroom observations should be considered to validate reported implementation and assess long-term impact.

Keywords: teacher tracer study, post-training implementation, teacher self-efficacy, science teaching motivation, epistemic beliefs, hands-on learning, STEM education, low-cost instructional materials, Ghana

Introduction

Globally, STEM education is increasingly recognized as critical for economic development, innovation, and workforce readiness [1]. Yet many education systems continue to struggle with low student engagement and weak learning outcomes in science subjects [2]. In response, hands-on and inquiry-based instructional approaches have gained prominence for their ability to improve conceptual understanding, learner motivation, and sustained interest in STEM through active participation and real-world problem solving [3], [4].

In low- and middle-income countries, these challenges are often compounded by limited instructional resources, overcrowded classrooms, and a continued reliance on teacher-centered pedagogies, particularly in science education [5], [6]. Across Sub-Saharan Africa, studies have shown that while curriculum reforms increasingly emphasize practical and learner-centered approaches, many teachers lack the materials, training, and institutional support required to implement them effectively [7], [8]. In Ghana, the 2019 national science curriculum for basic schools explicitly mentions activity-based and competency-driven learning [9], yet classroom practice frequently remains theoretical due to resource constraints and limited professional development opportunities. Empirical evidence from Ghana indicates that when teachers are supported in implementing hands-on science instruction with low-cost materials, students demonstrate improved achievement, more positive attitudes toward science, and greater interest in STEM-related careers [10].

Practical Education Network (PEN), a nonprofit organization registered in Ghana since 2017, addresses these challenges through a teacher training model [11]. The training equips STEM teachers to utilize locally available materials for hands-on instruction, providing a culturally-relevant approach within resource-constrained classrooms [12]. This training is a hands-on professional development program designed to deepen teacher capacity to implement inquiry-based learning and practical STEM activities in their classrooms. It combines in-person workshops, guided online learning, and structured follow-up support to create a rich, experiential learning journey. Participants receive a physical copy of PEN's Teacher Resource Manual, which serves as their key reference material after the training. The manuals include instructions for running hands-on activities aligned with each of the indicators in the national curriculum. These manuals have been approved by Ghana's National Council on Curriculum and Assessment for onward use. The blended learning model extends the workshop experience. Through a Learning Management System (LMS), teachers access online assignments, participate in community discussions, and receive periodic follow-up check-ins. This is used to ensure continuity of learning and provide ongoing guidance and feedback. Participants who complete 100% of the assignments and surveys are considered to have completed the training. They receive a certificate for this. Through various means, such as WhatsApp groups, Facebook community, and phone calls, the organization maintains some engagement with the participants after the end of the training duration.

PEN's approach is grounded in a theory of change which follows a sequential logic linking program inputs to long-term educational outcomes. It begins with the development of curriculum-aligned, low-cost, hands-on STEM materials and the delivery of structured teacher training workshops, complemented by ongoing follow-up support. These activities are expected to produce immediate outcomes at the teacher level, particularly successful completion of the training and increased confidence in implementing inquiry-based, hands-on instruction. As teachers gain confidence and practical competence, the model anticipates intermediate outcomes, such as sustained classroom implementation of hands-on methods. Through repeated use of experiential learning strategies, students are expected to become more engaged in STEM subjects, develop more positive attitudes toward them, and demonstrate improved academic performance in STEM subjects.

The present tracer study focuses specifically on the early and intermediate stages of this pathway. While long-term student and societal outcomes fall beyond the scope of the current investigation, this study seeks to understand whether key teacher-level mechanisms proposed in the theory of change are sustained over time. In this framework, teacher self-efficacy, science interest, and epistemic beliefs represent immediate outcomes, while continued implementation of hands-on science activities represents the intermediate outcome. Perceived support from PEN and from school-based professional communities functions as a reinforcing condition that may strengthen or weaken these pathways. By examining the relationships among these constructs, the study empirically assesses critical links within the theory of change, particularly the assumption that sustained support enhances teacher motivation, which in turn supports continued classroom implementation.

Although prior research documents short-term gains associated with hands-on and inquiry-based science instruction, empirical evidence on the long-term sustainability of such practices following teacher training interventions remains limited, particularly in low-resource contexts [8]. In many cases, studies focus on immediate post-training outcomes rather than examining whether instructional changes persist over time [8], [13]. This study seeks to address that gap by investigating whether teachers trained through PEN continue to implement hands-on science activities beyond the initial training period and by exploring factors that may be associated with sustained classroom practice.

Research Questions

This study focused exclusively on teachers in Ghana who participated in PEN's hands-on STEM teacher training program. Drawing on PEN's theory of change, the study examined the extent to which training effects are sustained over time, with particular attention to continued classroom practice, professional engagement, and teacher motivation. The following research questions guided the analysis:

- RQ1: To what extent do teachers engage with PEN after their initial training?
- RQ2: To what extent does engagement with PEN and other community support predict teachers' continued implementation and positive motivation?
- RQ3: To what extent does positive motivation predict continued implementation of hands-on science teaching?

Understanding these relationships is critical for assessing the theory of change underlying PEN's training program, which posits that sustained support fosters motivation and, in turn, ongoing instructional practice.

Methodology

Study Design

This study employed a quantitative approach to examine the research questions in view. The study focused exclusively on teachers and was designed as a stand-alone investigation of post-training implementation and motivation.

Study Participants

Participants were science teachers drawn from public junior high schools across six regions of Ghana. Teachers were selected using purposive sampling based on predefined eligibility criteria. To be included, teachers had to:
(a) be science teachers,
(b) have completed PEN's hands-on STEM training between 2018 and 2025, with completion defined as full attendance at all training sessions and submission of all required assignments leading to certification.

A database of eligible teachers was created in Excel and cross-verified against an internal beneficiary database maintained by PEN. All participants were contacted directly and provided informed consent before participation. Participation was voluntary, and teachers who completed the survey were reimbursed for mobile data costs incurred during survey completion.

A descriptive summary of participant characteristics (including region, gender, training year, and school type) is presented in Table 1. The distribution of participants across Ghana's Regions is shown with rounded percentages in Table 2.

Table 1. *Characteristics of Teacher Study Participants (N = 75)*

Characteristic	Category	n	%
School type	Public schools	75	100
	Private schools	0	0
School level taught	Junior High School (JHS)	75	100
Training completion status	Completed full training	75	100
Gender	Female	40	53
	Male	35	47

Table 2: *Regional Distribution of Participants*

Region	Number of Teachers	Percentage (%)
Greater Accra Region	36	48
Eastern Region	11	15
Western Region	3	4
Ashanti Region	9	12
Central Region	15	20
Volta Region	1	1
Total	**75**	**100**

Instrument Development

Data were collected using a structured survey designed to capture post-training implementation, perceived support, and motivational constructs related to science teaching. The instrument was adapted from previously validated teacher motivation and practice scales and contextualized to reflect PEN's training content and implementation environment.

The final survey included items across the following constructs:

- Continued implementation of hands-on science practices
- Epistemic beliefs about science teaching
- Science teaching self-efficacy
- Interest in teaching science
- Perceived ongoing support from PEN
- Perceived support from colleagues and school leadership

Most items used Likert-type response scales, which were numerically coded for analysis. Implementation items measured frequency of practice on a 1–6 scale, while support and motivation items used agreement-based scales.

Pilot Testing and Quality Control

Before full administration, the survey was piloted in-person with a small group of 5 teachers. These teachers shared similar characteristics with the target population but were not included in the final sample. The pilot focused on assessing clarity, comprehension, and contextual appropriateness of survey items rather than testing outcomes.

During the pilot testing, participants were asked to explain how they understood each question and to suggest alternative wording where items were unclear or contextually confusing. Feedback from this pilot informed revisions aimed at improving clarity and respondent friendliness. Importantly, no items were added or removed during this process, and no modifications were made that altered the underlying meaning or construct being measured. All changes were documented in a version-control log to ensure consistency and preserve instrument validity. Following revisions, a second and final version of the survey was produced and administered to the full study sample.

Data Collection

The finalized survey was administered electronically using Google Forms. A survey link was shared with 162 eligible teachers via WhatsApp, which was deemed the most reliable communication channel for reaching participants across the various Regions. Teachers completed the survey independently over a defined data collection window. Reminder messages were sent to improve response rates.

Data Analysis

Data from completed surveys (N = 75, representing 46% of the sample size) were exported and analyzed using R statistical software. Descriptive statistics were computed to summarize teacher characteristics, implementation frequency, and perceived support. Composite scale scores were created by averaging items within each construct. Internal consistency of multi-item scales was assessed using Cronbach's alpha, which indicated acceptable to excellent reliability across all major constructs.

To answer RQ1, two composite scales were analysed: PEN Support, which measured teachers' perceived level of ongoing engagement and support from PEN; and Other Support, which captured perceived support from colleagues and school leadership. Descriptive statistics, including means, standard deviations, and medians, were computed to summarize teachers' reported levels of support. The analysis was descriptive in nature, as the objective of this question was to establish the extent of engagement rather than to test predictive relationships.

To answer RQ2, a series of multiple linear regression models were estimated. Separate models were estimated to predict:

1. Implementation frequency of hands-on science activities
2. Teacher interest in science teaching
3. Teacher self-efficacy

These models tested whether support from PEN and from teachers' professional communities predicted continued implementation and motivation, while accounting for region and year of training. In all models, PEN Support and Other Support were included as predictors, while region and year of training were included as control variables to account for contextual differences. Significance was evaluated at the 5% level.

To answer RQ3, multiple linear regression analyses were conducted using teacher survey data. Two separate models were estimated:

1. Model 1: Epistemic beliefs and self-efficacy as predictors of implementation
2. Model 2: Science interest and self-efficacy as predictors of implementation

Region and year of training were included as control variables to account for contextual variation. Statistical significance was evaluated at the 5% level.

All analyses were conducted at the teacher level and interpreted as exploratory, given the cross-sectional nature of the data.

Results

This section presents the findings from the survey examining sustained engagement, motivation, and implementation of hands-on science practices following PEN training. All analyses are based on responses from 75 science teachers working in public Junior High Schools (JHS), reflecting the program's focus on strengthening science instruction within Ghana's public basic education system. All participants had completed their respective versions of the PEN training program, including all required assignments, ensuring a consistent level of training exposure across the sample. The gender distribution of respondents was relatively balanced, with female teachers comprising 53% of the sample and male teachers 47%. The results are structured to first establish the reliability of the measures, then address each research question using descriptive and regression analyses.

Reliability and Intraclass Correlation Analysis

Reliability analyses were conducted to determine whether composite scales could be created for each teacher construct. Cronbach's alpha was calculated for all constructs, as shown in Table 3. All scales showed acceptable to excellent reliability (α = 0.70–0.99), supporting the use of composite scores for subsequent analyses.

Table 3: *Cronbach's Alpha for Teacher Constructs*

Construct	# Items	α	Interpretation
Other Support	4	0.85	Excellent reliability; composite created
PEN Support	2	0.70	Acceptable for 2-item scale; averaged
Epistemic Beliefs	22	0.81	Acceptable; reliable composite
Science Interest	4	0.82	Good; coherent construct
Recognition	3	0.86	Strong; reliable measure
Implementation	3	0.99	Excellent; consistent uptake

To ensure that single-level regression models were appropriate, intraclass correlation coefficients (ICCs) were estimated for each construct using unconditional (null) random intercept models with teachers nested within schools. As shown in Table 4, ICC results indicated low to moderate clustering at the item level, but composite scale-level ICCs were sufficiently low to moderate that multilevel modeling was not required for this sample.

Teacher constructs demonstrated strong reliability at the scale level, and ICC analyses showed no evidence of school-level clustering that would necessitate multilevel modeling. Consequently, all subsequent analyses for RQ1–RQ3 were conducted using single-level regression models.

Table 4: *Intraclass Correlation Coefficients (ICCs) for Teacher Constructs*

Construct	ICC Result	Implication
Epistemic Beliefs	0.06 – 0.14	Use composite mean scores; single-level regression is sufficient
Science Interest	0.60 – 0.63	Single-level regression sufficient
Self-Efficacy	0.22 – 0.25	Single-level regression sufficient
Recognition	0.48 – 0.73	Single-level regression sufficient
Other Support	0.54 – 0.65	Single-level regression sufficient
PEN Support	Not stable	Single-level regression sufficient

Research Question One (RQ1)

A majority (63%) of respondents reported continued use of the PEN teacher resource manual. This serves as one indicator of their continued engagement with the content approach they were trained on. This suggests that the key program material tends to remain integrated into teachers' routines beyond the initial training period.

As seen in Table 5, teachers reported high levels of continued engagement with PEN after their initial training, with a mean score of 5.13 (SD = 1.03) on a six-point scale. The median score of 5.50 further indicates that most teachers perceived frequent and sustained support from the organization. In comparison, perceived support from colleagues and school leadership was moderately high (M = 4.30, SD = 0.73), though lower than support reported from PEN.

Table 5: *Descriptive Statistics for Teacher Engagement and Support (6-point scale)*

Scale	Mean	SD	Median	Min	Max
PEN Support	5.13	1.03	5.50	1.00	6.00
Other Support	4.30	0.73	4.40	1.00	5.00

Research Question Two (RQ2)

To capture overall implementation, a composite score was created by averaging teachers' reported frequency of referring to the PEN manual, using activities from the manual, and implementing hands-on activities, each measured on a six-point scale ranging from 1 (*once a year or less*) to 6 (*multiple times a week*). The mean implementation score was 2.86 (SD = 0.36, median = 2.80), placing the average response between *once a term* and *once a month*. Despite the scale spanning six response options, the full observed range ran only from 2.20 to 3.40, indicating that teachers' responses clustered within a narrow band.

Also, as seen in Table 6, neither PEN Support nor Other Support significantly predicted implementation frequency. The model explained approximately 26% of the variance (R^2 = 0.259), but the overall model was not statistically significant (F = 0.73, p = .699). As shown in Table 7, PEN Support also did not significantly predict teacher interest. Other Support did, however, emerge as a significant positive predictor of teacher interest in science teaching. In addition, teachers in the Volta Region reported significantly higher interest compared to other regions. These results suggest that school-based support from peers and leaders is more strongly associated with teacher motivation than support directly from PEN. While neither form of support significantly predicted actual implementation of hands-on activities, peer and leadership support were consistently linked to higher teacher interest and self-efficacy. This points to a potential disconnect between motivation and practice, highlighting the importance of school-level conditions in translating teacher confidence and enthusiasm into classroom behavior. As seen in Table 8, PEN Support did not significantly predict teacher self-efficacy.

Table 6: *Regression Results Predicting Implementation Frequency*

Predictor	B	SE	p-value
PEN Support	0.08	0.08	0.324
Other Support	-0.13	0.10	0.230
Region	-	-	>.60
Year of Training	-	-	>.40

Table 7: *Regression Results Predicting Teacher Interest*

Predictor	B	p-value
PEN Support	-0.08	.300
Other Support	0.27	0.008*
Volta Region	1.07	0.036*

Table 8: *Regression Results Predicting Teacher Self-Efficacy*

Predictor	B	p-value
PEN Support	-0.02	0.703
Other Support	+0.15	0.047

Research Question 3 (RQ3)

The results from Model 1 indicate weak, non-significant relationships between teacher epistemic beliefs and self-efficacy with implementation frequency (Table 9). Region and year of training had no meaningful effects. Similarly, in Model 2, neither science interest nor self-efficacy significantly predicted implementation of hands-on activities (Table 10). Both models explained roughly 27–29% of the variance in implementation ($R^2 = 0.277 - 0.288$), but negative adjusted R^2 values and non-significant F-tests indicated weak overall model performance.

Table 9: *Regression Results Predicting Implementation (Model 1)*

Predictor	B	p-value
Intercept	1.57	.170
Epistemic Beliefs	0.11	.544
Self-Efficacy	0.26	.221
Region & Training	-	> .40

Table 10. *Regression Results Predicting Implementation (Model 2)*

Predictor	B	p-value
Intercept	1.82	.091
Science Interest	0.07	.723
Self-Efficacy	0.22	.444
Region & Training	-	> .40

Discussion and Conclusion

In pursuit of adding to the understanding of what can enable meaningful pedagogical practice to be sustained in African contexts, this study engaged past participants from PEN's teacher training program. Drawing on survey data from 75 science teachers across six regions of Ghana, the study investigated continued implementation of hands-on activities, perceived support, and key motivational constructs, including self-efficacy, interest in science teaching, and epistemic beliefs. Reliability analyses confirmed acceptable to excellent internal consistency across all scales, supporting the use of composite scores for subsequent analyses.

Nearly all teachers continued to implement hands-on science activities even after up to 6 years of having been trained, with a majority (63%) still regularly using the PEN teacher resource manual. Regression analyses showed that neither PEN support nor broader community support significantly predicted the frequency of hands-on implementation. This suggests that while PEN has been effective in maintaining post-training engagement with teachers after program participation, this input may not be directly impacting implementation levels. The continued use of the teacher resource manual suggests that the training materials themselves may function as a stabilizing tool for practice. Even if school-based professional networks are weaker, structured resources may provide a reference point that sustains instructional continuity. This idea supports the design assumption that tangible, curriculum-aligned materials are critical for long-term pedagogical adoption in resource-constrained environments. The lack of a direct predictive relationship between perceived support and frequency of hands-on classroom implementation also reveals that implementation behavior may depend on additional enabling conditions beyond perceived encouragement. Factors such as instructional time constraints, examination pressures, classroom size, or material availability may limit teachers' ability to translate supportive relationships into observable practice. Thus, support may be necessary but not sufficient for sustained behavioral change. Even if teachers feel supported, other structural or contextual constraints may limit the actual enactment of hands-on activities.

Even though teachers tended to report lower levels of school-based support in their professional environments compared to levels of PEN support, their peer and school-based support emerged as a significant predictor of teacher motivation- particularly science interest and self-efficacy. PEN Support, on the other hand, did not significantly predict teacher self-efficacy. This finding suggests that teacher motivation may be more strongly influenced by day-to-day professional interactions within the school environment than by external organizational engagement. While PEN provides structured follow-up, school-based professional communities may offer more frequent and contextually embedded reinforcement, thereby strengthening teachers' sense of instructional competence.

Despite the strong correlation between peer/school-based support and teacher motivation, they did not directly predict implementation frequency. This reveals a possible gap between motivational reinforcement and behavioral enactment. The absence of statistically significant predictors in RQ3 also suggests that teacher motivation, while positively associated with implementation in direction, is insufficient on its own to account for sustained classroom practice. This finding challenges a simplified interpretation of the theory of change and suggests that structural or environmental factors may mediate the pathway from motivation to behavior. Specifically, while the theory of change assumes that increased self-efficacy and interest will drive classroom implementation, the regression models suggest that motivational variables alone explain limited variance in behavior. The negative adjusted R^2 values further indicate that the included predictors may not adequately capture the complexity of sustained instructional change. This underscores the likelihood that contextual constraints, institutional norms, or systemic pressures play a mediating role in shaping implementation patterns. Such a disconnect aligns with broader professional development literature, which suggests that shifts in teacher beliefs and attitudes do not always translate into consistent instructional change without structural reinforcement. The findings, therefore, partially support the motivational component of the theory of change while revealing the need for further investigation to understand additional conditions necessary for sustained practice.

Future work should expand on this preliminary study by expanding the sampling to a larger proportion of PEN's training population. Additional dimensions to the measurements should be included as well. Importantly, classroom observations should be conducted to validate self-reported implementation levels, as the analysis relies heavily on these values, and the standard deviation of those self-reported scores was low here. More experimentation should be conducted to determine what levers can best influence implementation frequency post-training. Insights gained can be used by PEN and other African teacher training organizations to improve their models. For example, if peer and school-based support is a lever for increasing motivation, these organizations may consider shifting focus from follow-up engagement with trainees to reinforcing school-based support mechanisms. Potential approaches include peer demonstration sessions, lesson-planning support, and light-touch instructional coaching. Expansion of this study through larger samples, longitudinal designs, and classroom observations can capture more detailed variation in practice and deepen understanding of how support, motivation, and contextual factors interact over time.

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