
USING A SCHOOL CONSTRUCTION SITE AS AN AUTHENTIC LEARNING ENVIRONMENT FOR DEVELOPING PRECISION AND ACCURACY COMPETENCES IN FORM 1 PHYSICS

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ABSTRACT

Precision and accuracy are foundational concepts in physics and engineering, yet they are frequently taught through decontextualised classroom exercises that limit meaningful application. This study investigates the use of a live school construction site as an authentic learning environment for developing precision and accuracy competences among Form 1 STEM learners under the 2023 Zambian Competence-Based Curriculum (CBC). Guided by four research questions, the study examined how construction-site engagement influenced conceptual understanding, instrument competence, error identification, ethical awareness, and implications for competence-based STEM implementation. A qualitative case study design was employed over three scaffolded 80-minute sessions conducted within one week. Data were collected through photographic and video documentation, learner measurement records, field notes, and group discussions, and analysed using thematic analysis complemented by descriptive comparison of measurement data. Learners measured wall dimensions, slab areas, and reinforcement bar diameters using metre rules, measuring tapes, Vernier calipers, and micrometer screw gauges under teacher facilitation and expert scaffolding from site personnel. Findings indicate that conceptual differentiation between precision and accuracy emerged through repeated measurement and comparison with design specifications. Instrument-handling proficiency improved progressively, including systematic zero-error correction and reduction of parallax. Learners developed structured error analysis skills and demonstrated ethical reasoning by linking measurement accuracy to structural integrity, budgeting, and safety. The study concludes that school infrastructure projects can serve as

powerful, low-cost learning environments for competence-based STEM education, enabling measurement concepts to become visible, accountable, and professionally meaningful.

KEYWORDS: Precision and Accuracy; Competence-Based Education; STEM Education; Authentic Learning Environment; Measurement Competence; Construction-Site Pedagogy.

INTRODUCTION

Measurement underpins physics as both conceptual foundation and practical discipline. Precision and accuracy are central not only to experimental validity but also to engineering reliability, structural safety, and resource efficiency. Despite their importance, these concepts are frequently taught through decontextualised exercises that prioritise procedural repetition over analytical reasoning. As a result, learners often memorise definitions without developing the capacity to evaluate measurement reliability in authentic situations (Hodson, 2014).

Contemporary science education scholarship emphasises inquiry, scientific practice, and real-world application (National Research Council [NRC], 2012; Osborne, 2014). Situated learning theory further posits that knowledge develops through participation in meaningful social and material contexts (Lave & Wenger, 1991). However, within many African STEM reform contexts, research highlights persistent gaps between curriculum intention and classroom practice, including limited authentic task design, inadequate contextualisation, and continued overreliance on theoretical instruction (Banda, 2021; Sakala, 2022). These challenges suggest that curriculum reform alone is insufficient without corresponding shifts in pedagogical practice.

The 2023 Zambian Competence-Based Curriculum (CBC) requires learners to demonstrate precision and accuracy in measuring length and determining area using appropriate instruments such as metre rules, vernier calipers, and micrometer screw gauges (Ministry of Education, 2023). Yet demonstration of competence demands contexts where measurement has visible consequence. Without authentic application, distinctions between precision and accuracy remain abstract.

This study responds to that gap by situating a Form 1 physics lesson within a live school construction site, where walls, slabs, and reinforcement bars became objects of investigation and learners assumed roles analogous to quality inspectors. The intervention was structured over three scaffolded meetings to allow conceptual understanding to emerge through guided

activity before formal articulation. This approach aligns with emerging African scholarship advocating for locally grounded, practice-based STEM learning environments that bridge curriculum reform with contextual relevance (Phiri, Sakala, & Banda, 2025).

Research Questions

The study was guided by the following questions:

1. How does engagement in a live construction-site environment influence learners' conceptual understanding of precision and accuracy?
2. How does such engagement affect demonstration of instrument-based measurement competence?
3. How does participation in authentic measurement tasks shape learners' error identification and ethical reasoning?
4. What implications does this model hold for competence-based STEM implementation in resource-constrained contexts?

By embedding measurement within a consequential engineering setting, the study examines whether precision and accuracy can shift from definitional knowledge to accountable scientific practice.

MATERIALS AND METHODS

Research Design

A qualitative case study design (Yin, 2018) was employed to examine a bounded instructional intervention conducted over one week. The focus was not experimental comparison but in-depth analysis of learner performance within a real-world context. The design prioritised naturalistic observation, situated participation, and competence demonstration.

Participants and Context

Participants were Form 1 STEM learners (approximately 12–13 years old) enrolled at a provincial STEM secondary school in Zambia operating under the 2023 CBC. Learners were organised into collaborative groups of four to five to promote peer reasoning, repeated measurement, and collective error analysis.

The intervention occurred at an active school construction site containing wall structures, slab foundations, reinforcement bars, trenches, and unfinished openings. The environment was

selected intentionally for its authentic variability and visible structural implications, ensuring that measurement outcomes had practical relevance.

Instructional Structure

The intervention was implemented over three structured 80-minute meetings within one week. The instructional design followed a scaffolded progression from experiential engagement to conceptual consolidation and ethical integration. Rather than beginning with direct exposition of definitions, the sequence was deliberately organised so that conceptual understanding emerged from authentic measurement activity before formal articulation.

Meeting 1: Safety Orientation and Emergent Measurement Engagement

The first session commenced at the construction site with a structured safety orientation conducted by the site engineer and builder. Learners were briefed on restricted zones, safe movement, tool handling, and professional conduct within an active engineering environment. This framing established the site as a legitimate professional workspace rather than an informal extension of the classroom.

Learners were then introduced to the task through problem-posing questions grounded in the construction context (e.g., how builders verify wall alignment and dimensional correctness). Under teacher and engineer guidance, learners received site-based orientation to measurement instruments, including calibration procedures, zero-error checking, avoidance of parallax, correct unit recording, and appropriate significant-figure reporting. These procedural elements were introduced responsively as challenges emerged during initial measurement attempts.

Working in collaborative groups, learners measured horizontal wall lengths and vertical heights, recorded three repeated readings, and calculated mean values. Through reflective questioning and group comparison, learners began distinguishing between consistency in repeated readings and closeness to the builder's reference value. Formal terminology was intentionally withheld at this stage to allow conceptual differentiation to arise inductively.

Meeting 2: Comparative Analysis and Conceptual Consolidation

The second session began with review of previously recorded measurements and discrepancies across groups. Guided questioning prompted learners to evaluate which

measurements were most consistent and which were closest to the design specification. At this point, the formal terms *precision* and *accuracy* were introduced and explicitly mapped onto learners' prior experiences.

Learners then extended measurement tasks to include determination of slab area. After measuring slab length and width, they calculated area and compared results across groups. This multiplication process revealed how small linear deviations could produce amplified discrepancies in derived quantities. Builders contextualised these differences by explaining implications for cement estimation and budgeting.

The session concluded with reinforcement diameter measurements using Vernier calipers and micrometer screw gauges. Learners compared readings across instruments, revisited zero-error correction, and discussed instrument resolution and systematic deviation. This phase deepened analytical reasoning beyond procedural measurement.

Meeting 3: Quality-Control Simulation and Ethical Integration

The third session consolidated learning through a structured quality-control simulation. Learners were assigned professional roles—measurement inspectors, data analysts, and quality verification team members—and tasked with re-measuring selected structures. Groups produced structured reports including mean values, deviation from design specifications, identified error sources, and proposed improvement strategies.

Reports were reviewed by the site engineer and builder, who provided professional feedback aligned with engineering standards. This evaluation process reinforced accountability and accuracy verification.

The session concluded with guided reflection on structural integrity, material efficiency, budgeting accuracy, and safety implications of inaccurate measurement. Learners articulated definitions of precision and accuracy grounded in site experience and produced written explanations linking conceptual understanding to authentic practice.

Pedagogical Progression Across Meetings

The three-meeting structure was intentionally sequenced to support competence development:

- Experience before terminology
- Comparison before classification
- Application before abstraction
- Reflection before consolidation

This progression enabled learners to move from experiential observation to conceptual articulation and finally to professional and ethical integration of measurement practice.

Instruments

Learners used:

- Metre rules
- Measuring tapes
- Vernier calipers
- Micrometer screw gauges

Orientation to calibration, zero-error checking, parallax avoidance, unit recording, and significant figures was embedded within performance challenges rather than delivered as pre-lesson instruction.

Learning Tasks

Learners performed three core tasks:

1. **Wall Measurement:** Repeated measurement of horizontal and vertical dimensions; calculation of mean values.
2. **Slab Area Determination:** Measurement of length and width; calculation of area and comparison across groups.
3. **Reinforcement Diameter Analysis:** Comparative measurement using calipers and micrometers; examination of instrument resolution and zero error.

In Meeting 3, learners assumed roles (measurement inspectors, data analysts, quality verification team) and produced structured reports evaluated by site personnel.

Data Collection

Multiple qualitative data sources were collected to ensure triangulation:

- Photographic documentation
- Video recordings
- Learner measurement record sheets
- Teacher field notes
- Group discussion transcripts

Data Analysis

Data were analysed using thematic analysis (Braun & Clarke, 2006). Coding combined deductive categories derived from the research questions with inductive themes emerging from learner behaviour.

Primary themes included:

- Conceptual differentiation
- Instrument competence
- Repetition and consistency
- Error identification
- Ethical awareness

Measurement tables were also examined descriptively to assess variability, group differences, and alignment with design specifications.

Trustworthiness

Credibility was strengthened through methodological triangulation, peer debriefing with STEM educators, member checking during discussions, and thick contextual description. These procedures align with established qualitative research standards.

Ethical Considerations

Permission was obtained from school administration prior to implementation. Learner safety was prioritised through structured orientation and continuous supervision. Construction personnel were informed of the instructional purpose to ensure coordinated and safe engagement.

RESULTS AND DISCUSSION

Findings are organised according to the three-meeting instructional progression: emergent understanding (Meeting 1), conceptual consolidation (Meeting 2), and ethical integration (Meeting 3).

Meeting 1: Safety Orientation and Emergent Measurement Engagement

Safety Orientation and Professional Framing of the Learning Environment

Although primarily procedural, the safety orientation conducted at the beginning of Meeting 1 had observable pedagogical impact on learner engagement and accountability. The structured briefing by the site engineer established restricted zones, safe tool handling protocols, and professional conduct expectations within the construction environment. This framing repositioned the site from a casual extension of the classroom to a legitimate engineering workspace governed by standards and responsibility. Learners demonstrated heightened attentiveness, deliberate movement, and disciplined instrument handling following the orientation. The professional tone of the environment influenced learners' perception of measurement as consequential rather than routine, laying the foundation for subsequent analytical and ethical reasoning. Thus, the safety orientation functioned not merely as compliance protocol but as an instructional catalyst that contextualised precision and accuracy within a culture of professional accountability.

As illustrated in Figure 1, the structured safety briefing positioned the construction site as a professional engineering environment and established procedural accountability prior to learner engagement.



Figure 1. *Safety orientation conducted by the site engineer prior to measurement activities, outlining restricted zones, tool handling procedures, and professional conduct within the construction environment.*

Emergent Differentiation Between Repeatability and Correctness

During the first engagement, learners measured pillar wall segments without revisiting textbook definitions. Repeated measurement revealed minimal variation (± 0.03 m across groups), as shown in Table 1.

Table 1: Sample Repeated Wall height Measurements. (Group A)

Trial	1	2	3	Mean
Measured height (m)	4.02	4.01	4.02	4.02

While initial perceptions equated “good measurement” with correctness, group comparisons exposed subtle discrepancies between consistent readings and the builder’s reference value. Through guided questioning, learners began distinguishing between closeness of repeated values and closeness to a design specification. By the end of the session, precision was informally described as “how close the numbers are to each other,” reflecting conceptual emergence through lived contrast rather than pre-instruction.

This shift demonstrates that experiential engagement supported early conceptual differentiation between repeatability and correctness.

Meeting 2: Comparative Analysis and Conceptual Consolidation

Precision and Accuracy in Relation to Design Specifications

Comparison with the builder’s 4.00 m specification (Table 2) revealed a small deviation (0.02 m; 0.5%). Although measurements were internally consistent, learners recognised that precision did not guarantee accuracy. The engineer’s explanation of cumulative structural effects—such as roof misalignment resulting from slight wall deviations—translated numerical difference into practical consequence.

Table 2: Comparison with Design Measurement.

Measured (m)	Mean	Design Value (m)	Absolute Difference (m)	Percentage Error (%)
4.02		4.00	0.02	0.5

The concept of accuracy was therefore consolidated not as abstract correctness but as alignment with functional design standards.

Slab Area Determination and Error Amplification

During Meeting 2, learners extended their measurement tasks from linear dimensions to the determination of slab area by measuring length and width and applying the relationship $\text{Area} = \text{Length} \times \text{Width}$. Unlike controlled classroom examples, the unfinished concrete slab presented surface irregularities, edge inconsistencies, and minor alignment challenges that introduced authentic measurement variability. As groups compared their calculated areas, small differences in recorded length and width values became magnified through multiplication, producing noticeably larger discrepancies in area estimates. This amplification effect prompted learners to recognise that seemingly minor linear deviations could significantly influence material estimation, budgeting, and structural planning. Through guided discussion, learners connected quantitative variation to practical implications, including cement allocation and layout accuracy. The task therefore deepened conceptual understanding of accuracy by demonstrating that measurement precision in foundational dimensions directly affects the reliability of derived quantities. In this way, slab area determination served not only as a computational exercise but as an applied illustration of error propagation within real engineering contexts.

As shown in Table 2, small variations in measured length and width values produced amplified discrepancies in calculated area, illustrating how minor linear deviations become magnified through multiplication.

Table 2: Illustration of Error Amplification in Slab Area Determination Across Six Groups.

Group	Length (m)	Width (m)	Calculated Area (m ²)	Deviation from Reference Area (m ²)
Reference (Design)	6.00	4.00	24.00	0.00
A	6.02	4.00	24.08	+0.08
B	6.00	4.03	24.18	+0.18
C	5.98	3.99	23.86	-0.14
D	6.01	4.02	24.16	+0.16
E	5.99	4.01	24.04	+0.04
F	6.03	3.98	24.00	0.00

Although linear differences are small (± 0.02 – 0.03 m), multiplication produces noticeably larger deviations in calculated area (up to ± 0.18 m²). This clearly evidences that:

- Minor measurement variation become magnified in derived quantities
- Precision in foundational dimensions directly affects reliability of computed results

- Small systematic or random errors accumulate meaningfully

As shown in Figure 2, the uneven slab surface and extended tape alignment introduced natural variability, prompting learners to consider reference consistency and the amplification of small linear deviations in area calculations.



Figure 2. *Learners measuring slab length across an unfinished concrete surface during Meeting 2, illustrating authentic variability and collaborative data recording influencing area calculation accuracy.*

Instrument Competence Progression

Instrument handling improved progressively across the three meetings (Table 3). Early misalignment, tape sagging, and overlooked zero errors gave way to systematic verification and peer cross-checking by Meeting 3. Learners independently corrected tape tension and verified micrometer calibration prior to recording values.

Table 3: *Instrument Competence Progression Across Meetings*

Instrument	Meeting 1 Observation	Meeting 3 Observation
Metre rule	Misalignment and inconsistent eye-level reading	Correct alignment and peer correction
Measuring tape	Loose tape tension, slight sagging, inconsistent reference point	Proper tape tension maintained and consistent baseline reference used
Vernier calipers	Difficulty interpreting Vernier scale	Accurate reading with confidence and independent verification
Micrometer screw gauge	Zero error often ignored	Zero-error correction applied systematically before measurement

The construction setting, characterised by material irregularity and real consequences, appeared to accelerate disciplined measurement practices beyond what is typically observed in controlled laboratory conditions.

As illustrated in Figure 3, learners adopted disciplined body positioning and peer cross-checking practices, reflecting measurable progression in instrument fluency and procedural accuracy.



Figure 3. *Learners collaboratively verifying vertical pillar measurements during Meeting 3, demonstrating improved instrument alignment, eye-level reading, and peer-assisted accuracy verification as they take turns to read measurements.*

Error Identification and Analytical Reasoning

Material variability—including uneven surfaces and curved reinforcement rods—created authentic conditions for error recognition. Learners identified parallax, surface irregularities, tape misalignment, and zero error (Table 4). Importantly, they progressed from identifying errors to proposing mitigation strategies, such as maintaining consistent reference points and averaging repeated trials.

Table 4: Frequency of Error Types Identified During Group Discussion (n = 6)

Error Type	Number of Groups Identifying
Parallax error	6
Surface irregularity	5
Tape misalignment	4
Zero error	4

When caliper and micrometer readings differed slightly, learners engaged in discussion about instrument resolution and systematic deviation. This reflects movement from procedural execution toward analytical evaluation of measurement reliability.

Meeting 3: Quality-Control Simulation and Ethical Integration

The quality-control simulation prompted deeper reflection on the implications of measurement accuracy. Learners connected accurate measurement to structural integrity,

budgeting accuracy, material efficiency, and safety. Statements such as “If the diameter is smaller than required, the building becomes weak” illustrate the internalisation of measurement as professional responsibility rather than academic routine.

Table 5 provides structured evidence of the conceptual shift observed during the quality-control simulation, illustrating progression from technical execution to ethical and professional reasoning.

Table 5: Evidence of Conceptual Shift During Meeting 3 Quality-Control Simulation (n = 6 Groups)

Indicator	Evidence in Meetings 1–2 (Technical Focus)	Evidence in Meeting 3 (Ethical/Professional Focus)
Purpose of Measurement	“To get the correct value.”	“To make sure the building is safe and correct.”
Focus of Discussion	Comparing readings within group	Comparing readings against design tolerance and safety
Error Interpretation	“The numbers are different.”	“If this error continues, the wall will not align.”
Reinforcement Diameter	Reading scale values	Linking diameter deviation to structural strength
Slab Area Calculation	Performing Length × Width	Discussing cement estimation and budgeting impact
Zero Error Checking	Procedural correction	Framed as professional responsibility before reporting
Reporting	Recording measurements in notebooks	Presenting findings to engineer and defending conclusions
Accountability Language	Minimal reference to consequence	Explicit mention of safety, cost, and structural integrity

Importantly, the visibility of partially completed structures provided tangible reference points for consequence. Learners could physically observe alignment lines, reinforcement spacing, and slab boundaries, enabling them to connect numerical deviation with structural outcome. This concrete linkage between quantitative error and physical consequence appeared to deepen ethical awareness beyond what is typically achievable in controlled laboratory simulations. Measurement was reframed as an act of accountability embedded within real engineering practice. The simulation thus consolidated conceptual understanding while cultivating professional dispositions aligned with competence-based STEM education.

Pedagogical Implications

The pedagogical contrast summarised in Table 6 highlights a shift from explanation-first instruction to experience-first engagement. Learners transitioned from mechanical procedure to analytical reasoning, aligning with situated learning and authentic task principles.

Table 6: Pedagogical Comparison Between Conventional Laboratory Instruction and Construction-Site Model.

Conventional Laboratory Approach	Construction-Site Model
Idealised, uniform surfaces	Irregular real-world structures
Teacher-led explanation precedes activity	Learner experience precedes formal conceptualisation
Minimal real-world consequence	Visible structural and practical implications
Procedural repetition of tasks	Investigative reasoning and analytical comparison

The findings suggest that structured engagement within real infrastructure contexts enables measurement competence to become visible, accountable, and transferable.

CONCLUSION

This study investigated how engagement in a live construction-site environment influenced Form 1 learners’ development of precision and accuracy competences. Across three scaffolded meetings, learners progressed from recognising repeatability in measurement to formally differentiating precision from accuracy and ultimately integrating ethical awareness into professional measurement practice.

Conceptual clarity strengthened through experiential contrast rather than pre-teaching definitions. Instrument competence improved through repeated scaffolded practice, with observable gains in calibration, alignment, and peer verification. Exposure to authentic material variability deepened error analysis skills, while quality-control simulation fostered ethical reasoning linked to structural integrity and safety.

The findings demonstrate that school infrastructure projects can function as powerful, low-cost learning environments under competence-based education. When intentionally facilitated, such contexts allow STEM teachers to transform everyday school surroundings into structured competence-development spaces. Embedding physics within real engineering activity renders scientific practice visible, measurable, and professionally meaningful.

REFERENCES

1. Banda, B. (2021). Leadership and pedagogical transitions in competence-based STEM reform in Zambia. *African Journal of Educational Development*, 8(2), 45–60.
2. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
3. Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, 48(3), 23–48.
4. Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, 36(15), 2534–2553.
5. Kabombwe, Y. M., & Mulenga, I. M. (2019). Implementing the competence-based curriculum in Zambia: Challenges and prospects. *Journal of Curriculum Studies Research*, 1(2), 1–15.
6. Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
7. Ministry of Education. (2023). *Zambia education curriculum framework 2023*. Government of the Republic of Zambia.
8. National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.
9. Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, 25(2), 177–196.
10. Phiri, M. K., Sakala, C. N., & Banda, B. (2025). Revolutionising physics education: A case study on implementing concept-based learning in a STEM secondary school in Zambia. In *Proceedings of the New Perspectives in Science Education Conference* (pp. xx–xx).
11. Sakala, C. N. (2022). Contextual competence development in African STEM classrooms: Bridging curriculum reform and classroom practice. *International Journal of STEM Education Research*, 5(1), 33–49.
12. Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage Publications.