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Communities of Practice and Digital Pedagogy for Active Learning in Secondary Schools of West Hararghe Zone in Ethiopia

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Abstract

Background

Communities of practice (CoPs) are increasingly proposed as a mechanism for sustaining digital pedagogical innovation in smart learning environments. In developing contexts such as Ethiopia, however, empirical evidence on how CoP-based learning cultures support active learning in secondary schools remains limited.

Methods

A descriptive, cross-sectional mixed-methods survey was conducted in five woredas of West Hararghe Zone, Oromia Regional State, Ethiopia, selected by lottery from 20 woredas. Eight secondary schools were selected purposively. Using Yamane's formula at a 5% margin of error, 94 of 122 secondary science and other subject teachers and 136 of 205 Grade 11–12 students were selected through proportional stratified random sampling. All 6 principals and all 6 supervisors were included purposively. Questionnaires were analysed with SPSS version 26 using frequencies, percentages and means. Interview data from the 12 leaders were analysed thematically.

Results

Teachers' overall mean perception of active learning was 3.89 (High), implementation mean was 3.12 (Moderate), and teachers' perceived challenges mean was 3.67 (High). Students' mean perception of teacher-facilitated active learning was 3.54 (High). Qualitative analysis identified four themes: community-based professional support, infrastructure and resource constraints, teacher anxiety, and leadership and institutional culture.

Conclusion

Active learning practice in Ethiopian secondary schools is shaped by teachers' perceptions and competencies, but its sustainability depends on the quality of collegial communities of practice, reliable infrastructure, and institutional leadership. Policies should pair infrastructure investment with sustained, school-embedded communities of practice.

1. Introduction

Education systems worldwide are being reshaped by digital technologies. Science and other secondary subjects increasingly rely on simulations, data-analysis tools, online collaboration and adaptive learning platforms to move classrooms from teacher-centred delivery towards inquiry, collaboration and critical thinking [1, 2]. Digital pedagogy, understood as the purposeful integration of digital technologies with

sound pedagogical strategies, is central to this shift because it links technology use to learning goals rather than treating technology as an end in itself [3].

Access to technology, however, does not guarantee effective classroom integration. Teachers interpret policy, design instruction and guide students' experiences, so their beliefs, confidence and competence largely determine whether digital tools change practice [4, 5]. Where infrastructure is weak, these human factors become even more important. Ethiopia has articulated ambitious national digital education commitments, including Digital Ethiopia 2025, the Education and Training Policy and the Education Sector Development Programme [6, 7]. Implementation at the school level, particularly in rural and resource-limited settings, has lagged behind these aspirations because of unreliable electricity, limited internet connectivity, a shortage of functional devices and limited teacher preparedness [8, 9].

Professional development is often offered as the remedy, yet brief, one-off workshops have repeatedly failed to produce durable changes in practice [10]. Sustained, job-embedded models, in which teachers learn together over time, are more promising. Communities of practice (CoPs), defined as groups of people who share a concern or passion and deepen their knowledge through regular interaction [11, 12], offer such a model. Within a smart learning environment, which integrates adaptive technologies, learner-centred pedagogy and supportive institutional structures [13], a CoP can provide the peer support, shared repertoires and mutual accountability that individual teachers rarely sustain on their own.

Despite this potential, Ethiopian studies have concentrated mainly on ICT access and infrastructure, and few have examined how collegial communities of practice shape the implementation of active learning in secondary classrooms [8, 14]. The present study addresses this gap. It investigates secondary teachers' and students' experiences of active learning in a smart learning environment, the perceived challenges to implementation, and the role of community-based professional support and institutional conditions in sustaining digital pedagogical innovation.

1.1 Objectives of the Study

1. To describe teachers' and students' perceptions of the implementation of active learning in secondary schools.
2. To identify the challenges that teachers and students face in implementing active learning within a smart learning environment.
3. To explore, through school leaders' perspectives, how communities of practice and institutional conditions support or constrain the sustainability of digital pedagogical innovation.

1.2 Research Questions

RQ1

How do secondary teachers and students perceive the implementation of active learning?

RQ2

What challenges do teachers and students report in implementing active learning?

RQ3

How do principals and supervisors describe the role of communities of practice and institutional support in sustaining digital pedagogical innovation?

2. Review of Literature

2.1 Active Learning and Digital Pedagogy

Active learning shifts the locus of learning from the transmission of information to the learner's construction of knowledge through inquiry, discussion, problem solving and collaboration [15]. Constructivist and social constructivist theories provide its intellectual foundation: knowledge is built through experience and social interaction, mediated by language and cultural tools [16]. Digital pedagogy extends this vision by using technology to make active learning more accessible, personalised and inquiry-driven [3, 17]. In science and other secondary subjects, virtual laboratories, simulations and data-analysis software allow learners to explore phenomena that would otherwise be impractical to observe [2, 17].

The effectiveness of these approaches depends on the teacher. A technology may be available but still not be used if teachers doubt its usefulness, feel unprepared, or fear technical failure during lessons [19, 20]. Pedagogical beliefs also matter: teachers who hold constructivist views tend to use technology for inquiry and collaboration, whereas those with more traditional orientations tend to use it to deliver content [21].

2.2 Communities of Practice as a Sustaining Mechanism

Lave and Wenger [11] conceptualised learning as legitimate peripheral participation in communities of practice, and Wenger [12] later described three defining dimensions of such communities: mutual engagement, a joint enterprise, and a shared repertoire of resources, routines and language. In teacher education, CoPs and professional learning communities (PLCs) have been linked to improved practice because they create safe spaces for experimentation, peer feedback and collective problem solving [22, 23]. Antinluoma et al. [21] show that teachers who experiment with new strategies in their own classrooms, supported by peers, are more likely to sustain change. Thoughtfully organised professional development of this kind builds technical skill and pedagogical confidence, which in turn enables the self-efficacy needed to overcome resistance [27].

A CoP is therefore more than a training event. It is a standing social structure in which teachers learn through shared practice, which is why it is a promising route for sustaining innovation after external projects or workshops end [23, 25].

2.3 Smart Learning Environments

Smart learning environments (SLEs) are learning settings that use adaptive technologies, learning analytics and responsive pedagogy to support learners' engagement and achievement [13]. The concept emphasises not only the technological infrastructure but also the pedagogical design and the human support systems that make such environments work [13]. Consequently, the successful implementation of an SLE depends on teachers' capacity to orchestrate learning, which is precisely where communities of practice can contribute.

2.4 Teacher Competencies and Perceptions

Effective digital pedagogy requires integrated knowledge of content, pedagogy and technology. The Technological Pedagogical Content Knowledge (TPACK) framework describes this integration and explains why technological skill alone is insufficient [24, 25]. The Technology Acceptance Model (TAM) explains how perceived usefulness and perceived ease of use shape the decision to adopt a technology [18]. Social Cognitive Theory adds that self-efficacy, the belief in one's capacity to perform a behaviour, is a critical determinant of persistence in new practices [27]. Taken together, these frameworks suggest that teachers' perceptions (usefulness, attitude and efficacy) and competencies (knowledge, pedagogy and content integration) jointly shape the extent to which active learning is implemented.

2.5 The Ethiopian Context

Ethiopia's policy framework positions technology as an instrument for improving educational quality, relevance and equity [6, 7]. Nevertheless, implementation at school level is uneven. Persistent digital divides constrain access to reliable internet and functional devices, particularly in rural areas [8, 9]. Teachers' preparedness is also a concern, as many educators report limited confidence in ICT skills and insufficient mastery of integrated pedagogical approaches [9, 29]. Existing research has focused largely on macro-level indicators such as ICT access, leaving the human and social conditions that sustain innovation under-examined. This study responds to that gap.

2.6 Conceptual Framework and Hypotheses

Drawing on CoP theory, the smart learning environment concept, TAM, Social Cognitive Theory and TPACK, the study proposes that communities of practice shape teachers' perceptions and competencies, which in turn influence the practice of active learning. Contextual factors (leadership support, infrastructure and continuous professional development) are expected to moderate these relationships (Fig. 1).

H1

Teachers' positive perceptions of digital pedagogy are positively associated with their implementation of active learning.

H2

Teachers' digital pedagogical competencies are positively associated with the implementation of active learning.

H3

Community-based professional support and institutional leadership are perceived by school leaders as necessary conditions for sustaining digital pedagogical innovation.

3. Materials and Methods

3.1 Research Approach and Design

The study adopted a mixed-methods approach within a pragmatic paradigm, which prioritises the research problem and uses multiple methods to generate practical, actionable knowledge [31]. The research approach combined quantitative and qualitative strands. The research design was a descriptive survey, cross-sectional in nature, used to investigate current behaviours, attitudes, beliefs and practices without experimental manipulation. The qualitative strand was embedded within the survey to explain and contextualise the quantitative patterns [30].

3.2 Study Area

The study was conducted in West Hararghe Zone, Oromia Regional State, Ethiopia. West Hararghe Zone is located approximately 340 km east of Addis Ababa and is characterised by predominantly rural populations, limited educational infrastructure, and significant resource constraints. The zone comprises 20 woredas (districts) with varying levels of educational development. The zone was selected for its relevance to the national implementation of secondary education policy, its representation of typical low-resource educational contexts in Ethiopia, and its logistical accessibility to the research team.

3.3 Population

The quantitative population comprised 122 secondary school teachers and 205 Grade 11–12 students attending the selected schools in West Hararghe Zone. The qualitative population comprised 6 school principals and 6 supervisors (education officers) responsible for the schools and woredas in the study area.

3.4 Sampling Procedure

A multi-stage sampling procedure was used. In the first stage, five of the 20 woredas (25.0%) were selected at random by lottery. In the second stage, eight secondary schools were selected purposively to represent variation in students' achievement levels (high and low achievers), teachers' years of experience and schools' willingness to participate. In the third stage, teachers and students were drawn from these schools using proportional allocation and simple random sampling. Principals and supervisors were included purposively (100%). The sampling stages are summarised in Table 2 and Fig. 2.

3.5 Sample Size Determination (Yamane's Formula)

The sample size for teachers and students was determined using Yamane's [32] simplified formula, which is appropriate for finite populations when the population size is known:

$n = N / (1 + N \cdot e^2)$

where n is the sample size, N is the population size, and e is the level of precision (margin of error). A 5% margin of error (e = 0.05) was adopted, corresponding to a 95% confidence level.

For teachers

N = 122; n = 122 / (1 + 122 × 0.05^2) = 122 / (1 + 0.305) = 122 / 1.305 = 93.49. Rounded up to the next whole number, the required sample is **94 teachers**.

For students

N = 205; n = 205 / (1 + 205 × 0.05^2) = 205 / (1 + 0.5125) = 205 / 1.5125 = 135.54. Rounded up, the required sample is **136 students**.

For principals

N = 6; n = 6 / (1 + 6 × 0.05^2) = 6 / (1 + 0.015) = 6 / 1.015 = 5.91. Rounded up, the required sample is **6 principals** (purposive sampling).

For supervisors

N = 6; n = 6 / (1 + 6 × 0.05^2) = 6 / (1 + 0.015) = 6 / 1.015 = 5.91. Rounded up, the required sample is 6 supervisors (purposive sampling).

Principals (6) and supervisors (6) were all included purposively, as their population is small enough to be studied in full. The total sample for the quantitative strand was therefore 230 selected respondents (94 teachers and 136 students), and the qualitative strand comprised 12 interviews (6 principals and 6 supervisors), giving a total of 242 selected participants.

Table 1
Sample size determination using Yamane's formula (e = 0.05)

Group	Population (N)	Yamane calculation	Sample (n)	Sampling technique
Secondary teachers	122	122 / (1 + 122 × 0.0025) = 93.49	94	Proportional stratified random
Students (Grades 11–12)	205	205 / (1 + 205 × 0.0025) = 135.54	136	Proportional stratified random
School principals	6	6 / (1 + 6 × 0.0025) = 5.91	6	Purposive
Supervisors	6	6 / (1 + 6 × 0.0025) = 5.91	6	Purposive
Total	**339**	—	**242**	230 questionnaire + 12 interview

Note. Yamane formula $n = N/(1 + Ne^2)$, e = 0.05. Results rounded up to the next whole number. Principals and supervisors were selected purposively (100% of population).

Table 2
Multi-stage sampling procedure

Stage	Procedure	Outcome
1	Lottery (simple random) selection of woredas from the zone	5 of 20 woredas (25.0%)
2	Purposive selection of schools (achievement level, teacher experience, willingness)	8 secondary schools
3	Proportional allocation of teachers across the 8 schools	94 teachers (≈ 11.8 per school on average)
4	Proportional allocation and random selection of Grade 11–12 students	136 students (≈ 17.0 per school on average)
5	Purposive, full inclusion of school and education leaders	6 principals; 6 supervisors (12 interviews)

Note. Per-school averages are 94/8 and 136/8. Actual allocation for each school follows $n_h = n \times N_h / N$, where N_h is the school's population of teachers or students.

3.6 Data Collection Instruments

Two instruments were used. The first was a four-part structured questionnaire administered to teachers and students. Part A collected background information; Part B measured the implementation of active learning; Part C measured perceptions (usefulness, attitude and efficacy); and Part D identified challenges. Items used a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Some items were adapted from Steers and Braunstein [35] and the remaining items were developed by the

researchers based on the literature reviewed. The teachers' questionnaire was prepared in English. The students' questionnaire was prepared in Afan Oromo and translated into English for analysis.

The second instrument was a semi-structured interview guide prepared in Amharic and transcribed into English. It was used with principals and supervisors to explore how communities of practice, leadership support, infrastructure and professional development shape the implementation of active learning.

3.7 Data Collection Procedure

After obtaining official permission from the West Hararghe Zone Education Office and relevant woreda education authorities, the questionnaires were distributed in person to the sampled teachers and students in their schools. Respondents were given the purpose of the study, assured of confidentiality and told that participation was voluntary. The questionnaires were collected on site. The 12 interviews were conducted in private settings at the convenience of the leaders and were recorded with consent, then transcribed.

3.8 Data Analysis

Quantitative data were analysed using SPSS version 26. Frequencies and percentages were used to describe respondents' background characteristics. Mean scores were calculated for each construct and item. To interpret mean scores on the five-point scale, the bands presented in Table 3 were applied.

Table 3
Interpretation of five-point Likert mean scores

Mean range	Interpretation	Level of agreement / implementation
1.00–1.79	Very low	Strongly disagree / never
1.80–2.59	Low	Disagree / rarely
2.60–3.39	Moderate	Neutral / sometimes
3.40–4.19	High	Agree / often
4.20–5.00	Very high	Strongly agree / always
Note. These bands were applied to all five-point scale means reported in this study.		

Qualitative interview data were analysed thematically using Braun and Clarke's [33] six-phase approach: familiarisation with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. A hybrid approach was used, combining deductive categories derived from the framework (perceptions, competencies, communities of practice and contextual factors) with inductive themes emerging from the data. Findings from both strands were integrated during interpretation to provide a richer understanding of the research questions.

3.9 Validity and Reliability

Content validity was strengthened through a review of the items by three experts in educational technology and science education, and a pilot study with 15 teachers from a non-participating woreda. Feedback from the pilot was used to refine item wording and clarity. Internal consistency of the scales was assessed using Cronbach's alpha, with coefficients of 0.70 or higher considered acceptable [34]. For the qualitative strand, trustworthiness was enhanced through triangulation of data sources, member checking, peer debriefing and maintenance of an audit trail.

3.10 Ethical Considerations

This study involved human participants and was conducted in accordance with the relevant guidelines and regulations and with the principles of the Declaration of Helsinki, as well as the national research ethics guidelines of Ethiopia. Ethical clearance and official permission were obtained from the Oda Bultum University Research Ethics Committee (Reference Number: OBU/EDU/2024/089) and the West Hararghe Zone Education Office. Informed consent was obtained from all adult participants (teachers, school principals and supervisors). Because some student participants were under 16 years of age, informed consent was also obtained from their parents or legal guardians before data collection, and the students themselves gave their assent to participate. Participants were assured of anonymity and confidentiality, and pseudonyms are used in all qualitative excerpts. Participation was voluntary and participants could withdraw at any time without consequence.

4. Results

The results are reported in four parts: respondents' characteristics, teachers' and students' perceptions of active learning implementation, challenges, and the qualitative findings from school leaders.

4.1 Respondents' Characteristics

Of the 94 teachers and 136 students sampled, 81 teachers and 124 students returned completed questionnaires, a response rate of 86.2% and 91.2% respectively (205 of 230 overall, 89.1%). All 6 principals and 6 supervisors participated in interviews. Table 4 summarises the background characteristics of the respondents.

Table 4
Background characteristics of respondents

Variable	Category	Teachers (n = 81)	Students (n = 124)
Sex	Male	49 (60.5%)	65 (52.4%)
	Female	32 (39.5%)	59 (47.6%)
Age (years)	20–29	19 (23.5%)	—
	30–39	36 (44.4%)	—
	≥ 40	26 (32.1%)	—
Teaching experience	< 5 years	21 (25.9%)	—
	5–10 years	34 (42.0%)	—
	> 10 years	26 (32.1%)	—
Subject taught	Biology	17 (21.0%)	—
	Chemistry	15 (18.5%)	—
	Physics	14 (17.3%)	—
	Other subjects	35 (43.2%)	—
Grade level	Grade 11	—	64 (51.6%)
	Grade 12	—	60 (48.4%)
Access to digital device at school	Yes	56 (69.1%)	81 (65.3%)
	No	25 (30.9%)	43 (34.7%)

Note. Frequencies and percentages computed in SPSS version 26.

4.2 Teachers' Perceptions and Implementation of Active Learning (RQ1)

Teachers reported generally favourable perceptions of active learning. The mean score for perceived usefulness was 3.92 (SD = 0.68), indicating a high level of agreement that digital pedagogy is valuable for student learning. Attitude toward digital pedagogy was 3.85 (SD = 0.72), indicating a favourable disposition. Averaging the usefulness and attitude scores gives an overall teacher perception score of 3.89 (High), the value reported in the abstract. Self-efficacy in applying digital tools to active learning was 3.21 (SD = 0.81), which is moderate and suggests that confidence lags behind the value teachers attach to the approach. Implementation of active learning in lessons was 3.12 (SD = 0.79) (moderate), and 42.6% of teachers selected 4 or 5 (often or always) on the implementation items (Table 5).

Table 5
Teachers' perceptions and implementation of active learning (N = 81)

Construct	Mean	SD	% agree (4–5)	Interpretation
Perceived usefulness of digital pedagogy	3.92	0.68	71.6%	High
Attitude toward digital pedagogy	3.85	0.72	68.5%	High
Self-efficacy in digital pedagogy	3.21	0.81	48.1%	Moderate
Competence: pedagogical skill	3.34	0.74	52.5%	Moderate
Competence: content integration	3.28	0.77	49.4%	Moderate
Competence: technological knowledge	2.98	0.85	38.3%	Moderate
Implementation of active learning	3.12	0.79	42.6%	Moderate

Note. Interpretation bands as in Table 3. Percent agree = share of respondents selecting 4 or 5.

4.3 Students' Perceptions of Active Learning (RQ1)

Students' perceptions were examined on three dimensions: their experience of active learning activities, their perceived usefulness of digital tools for learning, and their confidence in using them. The overall mean across these dimensions was 3.54 (SD = 0.71) (High). Students reported 45.8% frequency of participation in group discussions and 38.7% in hands-on or simulation-based activities during science lessons.

Table 6
Students' perceptions of active learning (N = 124)

Dimension	Mean	SD	% agree (4–5)	Interpretation
Experience of active learning in lessons	3.48	0.76	56.8%	High
Perceived usefulness of digital tools	3.72	0.69	64.2%	High
Confidence in using digital tools	3.41	0.78	53.1%	High
Teacher support for active learning	3.56	0.73	58.3%	High
Overall perception	3.54	0.71	58.1%	High

4.4 Challenges in Implementing Active Learning (RQ2)

Teachers and students identified several challenges. The most frequently reported challenge was unreliable electricity (mean = 4.12 for teachers; 3.98 for students), followed by limited internet access (mean = 3.96 for teachers; 3.84 for students) and shortage of functional devices (mean = 3.89 for teachers; 3.76 for students). Lack of reliable electricity and internet access, insufficient functional devices, and limited technical skills were the most prominent items.

Table 7
Reported challenges to implementing active learning

Challenge	Teachers: mean (SD)	Teachers: % agree	Students: mean (SD)	Students: % agree	Rank
Unreliable electricity	4.12 (0.72)	78.4%	3.98 (0.76)	74.2%	1
Limited internet access	3.96 (0.78)	72.8%	3.84 (0.81)	69.7%	2
Shortage of functional devices	3.89 (0.74)	70.4%	3.76 (0.79)	66.8%	3
Limited technical skills	3.72 (0.82)	64.2%	3.58 (0.85)	59.4%	4
Fear of technical failure during lessons	3.65 (0.86)	61.7%	3.42 (0.88)	54.6%	5
Insufficient time for planning	3.58 (0.79)	58.6%	3.35 (0.82)	51.3%	6
Limited peer support / collaboration	3.44 (0.84)	54.3%	3.28 (0.87)	48.7%	7

4.5 Scale Reliability

The reliability coefficients for the main scales were above the recommended threshold, indicating acceptable internal consistency for the instrument.

Table 8
Cronbach's alpha for the questionnaire scales

Scale	Number of items	Cronbach's α (teachers)	Cronbach's α (students)
Perceived usefulness	5	0.84	0.81
Attitude	5	0.82	0.79
Self-efficacy	5	0.86	0.83
Competencies (TPACK-based)	12	0.88	—
Implementation of active learning	8	0.85	0.82
Challenges	10	0.87	0.84
Note. Acceptable reliability is α ≥ 0.70 (Nunnally, 1978) [34].			

4.6 Qualitative Findings from School Leaders (RQ3)

Thematic analysis of the 12 interviews with principals and supervisors generated four themes. Table 9 presents each theme with its description and an illustrative excerpt.

Table 9
Themes from interviews with principals and supervisors

Theme	Description	Illustrative excerpt (pseudonym)	Participants mentioning theme
1. Teacher anxiety and need for sustained support	Fear of technical failure and of making mistakes before students; benefit of continuous, hands-on professional development	“Many of our teachers are afraid to use technology in front of students. They worry that something will go wrong and they will lose respect. We need ongoing support, not just one workshop.” — Principal A	11 / 12
2. Gap between belief and practice	Positive views of digital tools do not translate into practice without skills to set up and link tools to the curriculum	“Teachers believe that digital tools can help students learn, but they do not know how to use them effectively. The gap between what they believe and what they do is very wide.” — Supervisor B	9 / 12
3. Infrastructure and functional resources	Shortage or unreliability of electricity, internet, and working devices	“We have computers, but the electricity goes out constantly. The internet is unreliable. Without these basics, even the most willing teacher cannot implement active learning.” — Principal C	12 / 12
4. Leadership, collegial communities and institutional culture	Encouragement from leaders and peer communities enables teachers to take risks with technology	“When teachers work together—planning lessons, observing each other, sharing what works—they gain confidence. The community of practice in our school has been more effective than any external training.” — Supervisor D	10 / 12

4.7 Integration of Quantitative and Qualitative Findings

The qualitative findings help explain the quantitative patterns. Teachers’ high perceived usefulness (M = 3.92) and attitude scores (M = 3.85) coexisted with moderate self-efficacy (M = 3.21) and implementation scores (M = 3.12). School leaders attributed this discrepancy to skill gaps, anxiety and infrastructure constraints. The theme of collegial support, which was rarely a feature of the quantitative instrument, emerged in the interviews as the mechanism through which teachers moved from belief to practice.

5. Discussion

5.1 Perceptions and Implementation of Active Learning

The findings indicate that teachers and students value active learning and digital tools, yet actual implementation remains moderate. This is consistent with TAM, which suggests that perceived usefulness is an important precursor to adoption [18]. However, the gap between attitude and practice shows that positive perceptions are not sufficient on their own. This supports the view that teachers' dispositions must be accompanied by the capacity and conditions required to act on them [4, 20].

The moderate implementation scores (M = 3.12) align with previous research in Ethiopian secondary schools, which has documented persistent gaps between policy aspirations and classroom realities [8, 9]. The finding that only 42.6% of teachers selected 4 or 5 on the implementation items suggests that traditional, teacher-centred approaches remain prominent, despite favourable attitudes toward change.

5.2 Competencies and the Sustainability of Practice

Teachers' moderate pedagogical (M = 3.34) and content integration (M = 3.28) competencies, combined with lower technological knowledge (M = 2.98), suggest that the integrated TPACK capacity required for effective digital pedagogy is still developing [24, 25]. Social Cognitive Theory helps explain why: mastery experiences with technology build self-efficacy, which in turn sustains engagement [27]. Without such experiences, confidence remains low even where the value of the approach is accepted.

The finding that self-efficacy (M = 3.21) was lower than perceived usefulness (M = 3.92) and attitude (M = 3.85) highlights a critical gap in professional development. Teachers believe in the value of digital pedagogy but lack confidence in their ability to implement it effectively. This suggests that professional development should focus not only on knowledge and skills but also on building confidence through practice, feedback and peer support.

5.3 The Role of Communities of Practice

The qualitative data suggest that communities of practice are the mechanism through which perception and competence are translated into sustained practice. Leaders described teachers who experimented more readily when they had peer support, shared lesson resources and encouragement from supervisors. This is consistent with the CoP framework, in which learning is social, situated and sustained through mutual engagement [11, 12]. It also aligns with evidence that job-embedded, ongoing support is more effective than one-off workshops [10, 22].

The finding that 10 of 12 leaders mentioned community-based professional support as critical to sustaining innovation underscores the importance of social learning structures. Leaders described schools in which collaborative planning and peer observation were routine as better placed to sustain practice. This suggests that CoPs can serve as a buffer against the isolating effects of large class sizes, heavy workloads and limited external support.

5.4 Infrastructure and Institutional Conditions

Structural barriers, including unreliable electricity, limited internet and insufficient devices, were consistently reported. These conditions limit what even a well-prepared teacher can achieve.

Infrastructure investment is therefore a necessary, though not sufficient, condition for sustainable digital pedagogy; it must be combined with leadership and community support, as argued in the smart learning environment literature [13].

The finding that all 12 leaders mentioned infrastructure constraints highlights the severity of these barriers in West Hararghe Zone. Unlike previous studies that have focused primarily on access, this study shows how infrastructure limitations interact with human and social factors to constrain implementation. Even teachers with positive attitudes and moderate competencies cannot implement active learning effectively when basic infrastructure is unreliable.

5.5 Theoretical Contribution

This study suggests an extension of TAM and SCT: high perceived usefulness and favourable attitudes can be undercut by low self-efficacy and limited technological understanding, and collegial communities of practice may bridge this gap in low-resource settings. It thus positions communities of practice as a sustaining mechanism within smart learning environments, linking the CoP and SLE frameworks in a developing-country context.

The study also contributes to the literature on digital pedagogy in Sub-Saharan Africa by providing contextually grounded evidence from an under-researched setting. It indicates that the principles of active learning and digital pedagogy are relevant and potentially transformative in low-resource contexts, but their implementation requires careful attention to local conditions and constraints.

6. Conclusion

Secondary school teachers and students in West Hararghe Zone generally hold positive attitudes toward active learning and digital pedagogy, but implementation is constrained by low self-efficacy, moderate competencies and structural barriers. Communities of practice, supported by school leaders, offer a practical route to converting positive perceptions into sustained classroom practice. Sustaining digital pedagogical innovation in Ethiopian secondary schools therefore requires a combined strategy: strengthening teachers' integrated competencies, establishing school-embedded communities of practice, and investing in dependable infrastructure and institutional support.

7. Limitations

Several limitations should be considered. First, reliance on self-reported questionnaires may introduce social desirability bias, leading respondents to overstate their competencies or practice. Second, the study was conducted in one zone of one region, so findings may not generalise to other parts of Ethiopia. Third, the cross-sectional design limits causal inference and does not capture change over time. Fourth, the qualitative strand involved school leaders and supervisors only; the views of teachers and students were captured through the survey rather than in depth. A further limitation is that the hypotheses (H1–H3) were examined descriptively and not tested with inferential statistics, so the

relationships in Fig. 1 should be regarded as proposed rather than confirmed. Finally, the sample was drawn from eight purposively selected schools, which may not represent the full range of school conditions in the zone.

8. Implications

8.1 Theoretical Implications

The study integrates CoP theory, SCT, TAM and TPACK to explain digital pedagogy in a smart learning environment, and shows that perceptions and competencies interact with social and institutional conditions to shape practice. It offers preliminary, descriptive evidence consistent with the conceptual framework, suggesting that communities of practice may serve as a mediating mechanism between individual teacher characteristics and sustained implementation.

8.2 Policy and Practice Implications

For policymakers, infrastructure investment (electricity, internet and functional devices) should be prioritised alongside teacher development. Professional development should move beyond one-off workshops to sustained, school-embedded communities of practice with coaching and peer support. School leaders should actively encourage experimentation and create protected time for collaborative planning. Curriculum developers should provide ready-to-use, context-appropriate digital activities for science and other subjects.

8.3 Methodological and Future Research Implications

Future research should use longitudinal designs to track changes after CoP interventions, include teachers' and students' qualitative accounts, and examine the effect of CoP participation on TPACK components and student learning outcomes. Comparative studies across Ethiopian regions would improve generalisability.

Declarations

Ethics approval and consent to participate: This study involved human participants. All procedures were performed in accordance with the relevant guidelines and regulations and in compliance with the principles of the Declaration of Helsinki and the national research ethics guidelines of Ethiopia. Ethical clearance was obtained from the Oda Bultum University Research Ethics Committee (Reference Number: OBU/EDU/2026/092) and official permission was obtained from the West Hararghe Zone Education Office. Informed consent to participate was obtained from all adult participants (teachers, school principals and supervisors). As some student participants were under 16 years of age, informed consent was obtained from their parents or legal guardians, and the students themselves gave assent to participate. Participation was voluntary, and participants could withdraw at any time without consequence.

Consent for publication:

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author contributions:

Author has conceptualized the study, designed the methodology, collected and analysed the data, drafted the manuscript, contributed to instrument development, data analysis, and critical revision of the manuscript.

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Figures

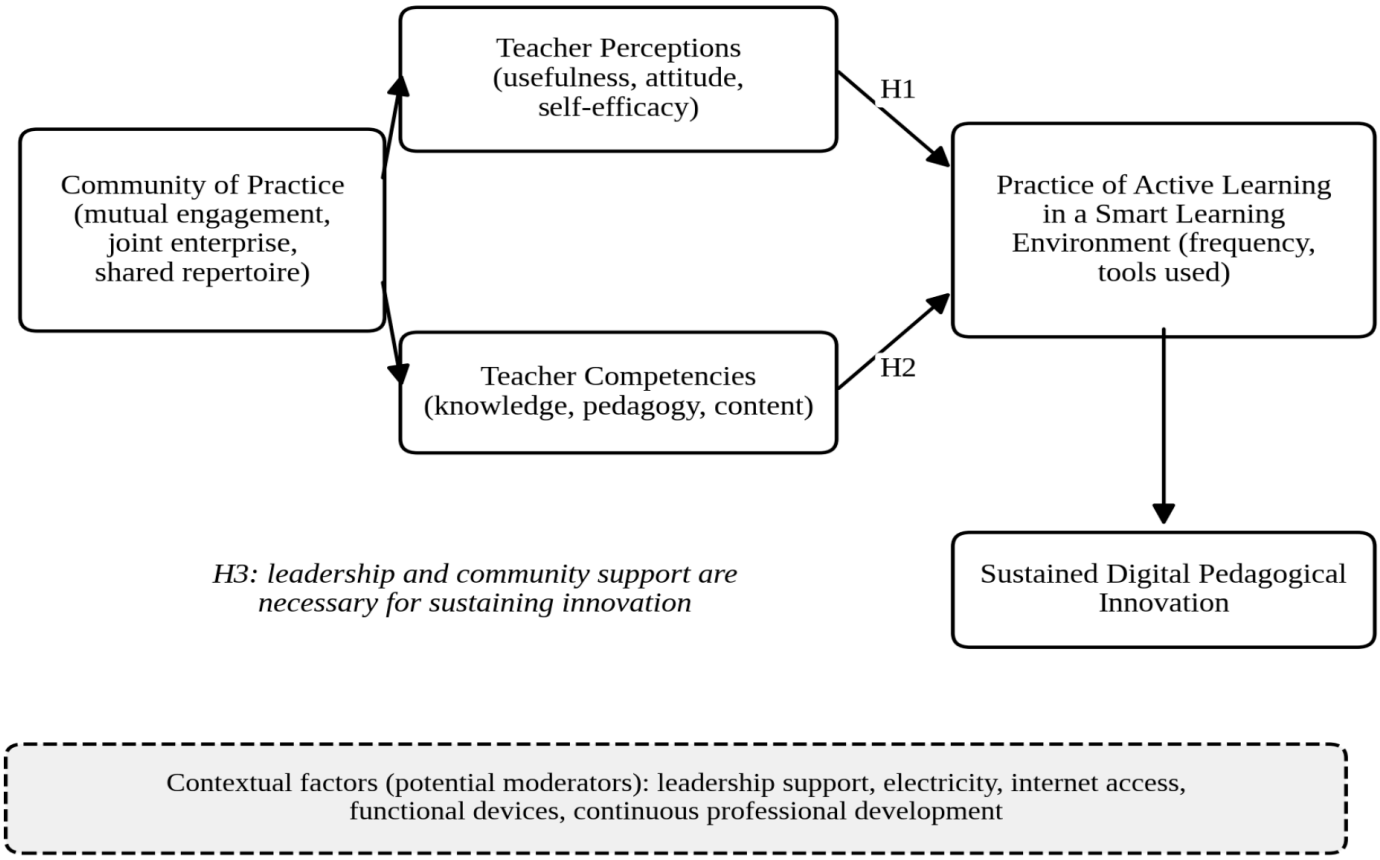


Figure 1

Conceptual framework of the study. *Note.*Perceptions and competencies are hypothesised to influence practice; contextual factors act as potential moderators.

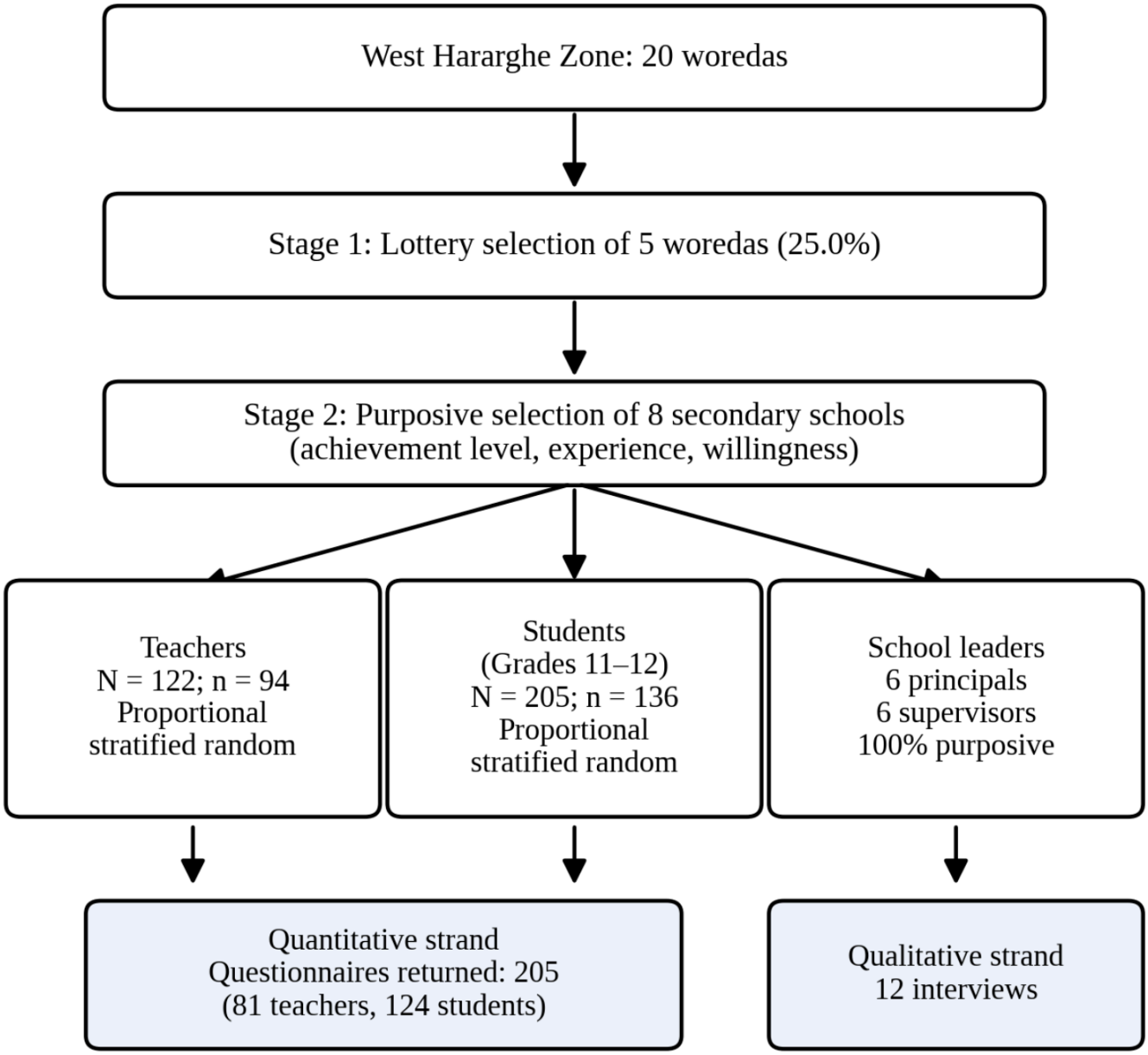


Figure 2

Multi-stage sampling procedure. *Note.*In the quantitative strand, 230 teachers and students were sampled and 205 questionnaires were returned.