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Digital Technology Use, Cognitive Engagement and Perceived Learning Effectiveness Among Adult Learners in Non-Formal Education in Uzbekistan

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Systematic Review

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Abstract

Although digital technologies are increasingly embedded in adult education policy, evidence from post-Soviet Central Asia remains scarce. This sequential explanatory mixed-methods study examined how digital technology use relates to two proximal indicators of learning processes – cognitive engagement and perceived learning effectiveness – among adults in non-formal education programmes in Uzbekistan. Survey data from 312 learners nested in 26 programmes across three provinces were analysed with two-level random-intercept models, followed by semi-structured interviews with 22 learners and two facilitators, analysed through reflexive thematic analysis. After adjustment for age, gender, educational attainment, urban–rural location and programme type, digital technology use was positively associated with cognitive engagement (β = .38, 95% CI [.27, .49]) and perceived learning effectiveness (β = .35, 95% CI [.24, .46]). Between 17% and 18% of the variance in each outcome lay at the programme level. Four qualitative themes – socially produced digital self-efficacy, peer-mediated learning, institutional culture and structural barriers – helped to explain these patterns. Interpreted through self-directed learning theory and the capability approach, the findings suggest that the educational value of digital tools depends on the social and institutional conditions in which adults use them. The cross-sectional design and reliance on self-report preclude causal inference.

Introduction

The integration of digital technologies into adult education is one of the most consequential developments in contemporary lifelong learning policy and practice. The rapid spread of digital technologies across everyday life challenges all citizens, including adults well beyond initial education, to learn digital skills continuously (Pihlainen *et al.* 2023). For the field of adult education, this development unsettles established assumptions about how adults learn, the conditions under which their learning is facilitated, and how responsibility for educational engagement is distributed across the life course. Mobile devices, open educational resources and digital communication platforms offer new ways of reaching adults who have been excluded from formal education, including those in remote regions, those with occupational and caregiving responsibilities, and those whose earlier educational experiences were marked by marginalisation. At the same time, critical scholarship cautions against the uncritical optimism that often surrounds educational technology (Selwyn 2016), and it underlines the need for empirical work that examines what digital tools actually do in particular educational settings.

In the Republic of Uzbekistan, these global developments intersect with a distinctive national context shaped by post-Soviet educational reform, economic liberalisation and a state-led modernisation agenda. Since independence in 1991, successive governments have restructured the national education system. The Action Strategy for 2017–2021 (President of the Republic of Uzbekistan 2017), the Digital Uzbekistan – 2030 Strategy (President of the Republic of Uzbekistan 2020) and the 2020 Law on Education, which recognises the education and advanced training of adults as a distinct type of education (Republic of Uzbekistan 2020), together position digital transformation and lifelong learning as national priorities. Non-formal adult education has received particular attention because a substantial

proportion of the adult population needs new competencies for a restructuring labour market (UNDP 2022).

Despite this policy momentum, rigorous empirical research on the relationship between digital technology use and indicators of learning processes in Uzbekistan, and in Central Asia more broadly, remains limited. The international literature is dominated by studies conducted in Western European, North American and East Asian settings (e.g. Mossberger *et al.* 2008, Tamim *et al.* 2011), which may not capture the structural, cultural and infrastructural specificities of post-Soviet transitional contexts. This geographical imbalance limits both theory development and policy design.

The present study addresses this gap by examining how adults in Uzbekistan engage with digital technologies within non-formal education programmes and how this engagement relates to two proximal indicators of learning processes: cognitive engagement and perceived learning effectiveness. These constructs are not equivalent to demonstrated learning outcomes, understood as objectively measured gains in knowledge or skill. Cognitive engagement refers to the degree of psychological investment in learning activities, including attention, effort and strategic processing (Fredricks *et al.* 2004). Perceived learning effectiveness denotes learners' subjective assessment of the extent to which their participation has produced meaningful learning. Although conceptually distinct from objective outcomes, both are meaningful proximal indicators: cognitive engagement is associated with academic achievement (Lei *et al.* 2018), and learners' perceptions of their progress are associated with persistence and continued participation (Beder and Medina 2001). The study therefore treats these constructs as indicators of learning processes rather than as direct measures of learning achievement.

Theoretical framework

Research on digital technologies in adult education draws on several intersecting theoretical traditions. Self-directed learning theory, articulated by Knowles (1975) and elaborated by Candy (1991) and Garrison (1997), provides a foundational lens for understanding how adults exercise agency in technology-mediated environments. Within this tradition, digital tools are potential amplifiers of learner autonomy – providing access to resources, enabling personalised pacing and supporting reflective practice – while also posing risks of cognitive overload for learners who lack adequate digital competence (Dabbagh and Kitsantas 2012). Garrison's (1997) model is particularly relevant here because it treats self-direction as the interplay of self-management, self-monitoring and motivation within a social context rather than as a purely individual trait.

The capability approach, developed by Sen (1999) and extended to education by Walker (2006) and Nussbaum (2011), offers a complementary framework that foregrounds equity and social justice. From this perspective, access to digital resources is insufficient for educational benefit; what matters is whether learners have the genuine capability to convert those resources into valued learning opportunities (Kleine 2013, Robeyns 2017). The distinction between resources and capabilities is

especially relevant to marginalised adult learners in low-resource contexts, where investment in information and communication technologies can reproduce rather than reduce inequality (Unwin 2017).

Engeström's (1987) cultural-historical activity theory provides a third resource, useful for understanding the collective and institutional dimensions of technology use. By directing attention to the tools, rules, community and division of labour that shape learning activity, activity theory situates technology use within wider social and organisational contexts (Daniels 2001). This orientation is pertinent to non-formal education programmes, in which institutional structures play a central mediating role. Taken together, the three frameworks guided the choice of individual-level predictors (self-directed learning), the attention to structural conditions (capability approach) and the analysis of programme-level variation (activity theory).

Digital technology use and proximal learning indicators

The empirical literature on digital technologies and learning is substantial but geographically concentrated. Second-order and conventional meta-analyses report small to moderate positive effects of technology-enhanced instruction, with effect sizes typically between $d = 0.20$ and $d = 0.45$ (Tamim *et al.* 2011, Means *et al.* 2013). These syntheses, however, draw predominantly on studies from high-income countries, and their applicability to transitional economies requires careful consideration.

Studies of adult learners have identified several moderating factors. Digital self-efficacy – an individual's belief in their capacity to use digital tools for learning – consistently predicts engagement (Compeau and Higgins 1995, Eastin and LaRose 2000). The relationship between age and technology use is complex: some studies report negative associations between age and technology adoption (Morris and Venkatesh 2000), whereas research published in this journal shows that older adults' participation in digital skills learning is driven by intertwined individual, social and technical reasons (Pihlainen *et al.* 2023). Institutional support – technical infrastructure, learner support services and facilitators' pedagogical competence – is a further determinant of learner experience (Beetham and Sharpe 2013, Bates 2015).

Much of this literature treats learning outcomes as a unitary construct, conflating proximal indicators (engagement, perceived effectiveness, satisfaction) with distal outcomes (measured skill acquisition, certification, employment transitions). The present study deliberately focuses on proximal indicators, acknowledging both their conceptual distinctness from objective outcomes and their practical value for understanding learning processes in settings where standardised objective assessment is not systematically available.

Adult education and digital technology in Central Asia

Research on digital technology and adult education in Central Asia is limited but growing. Seitkali *et al.* (2020) found that mobile device ownership was associated with participation in informal online learning

among adults in Kazakhstan, whereas structured non-formal programmes showed limited digital integration. Dzhaksybekov and Nurlanovna (2021) identified substantial barriers to e-learning adoption in Kyrgyzstan's vocational sector, including unreliable infrastructure and language issues. Research specific to Uzbekistan remains sparse. Abdullaeva and Karimov (2022) reported that facilitators in adult literacy programmes under-used available digital tools because of technical insecurity, and Yusupov *et al.* (2023) found that rural adults were less likely than urban adults to use digital technologies for learning, even after controlling for device ownership. To the author's knowledge, no study has used multilevel modelling to examine the association between digital technology use and proximal learning indicators across a multi-province sample of non-formal adult education programmes in Uzbekistan.

The present study

Using a sequential explanatory mixed-methods design, the study addressed three research questions:

RQ1. To what extent is digital technology use associated with cognitive engagement and perceived learning effectiveness among adults in non-formal education programmes in Uzbekistan, once the nesting of learners within programmes is taken into account?

RQ2. Which individual and programme-level characteristics are associated with these outcomes?

RQ3. How do adult learners and facilitators account for the ways in which digital technology use supports or constrains engagement across programme settings?

Methods

Research design

The study employed a sequential explanatory mixed-methods design (Creswell and Plano Clark 2018), in which quantitative data were collected and analysed first, followed by qualitative data collection designed to explain and elaborate the quantitative patterns. The quantitative phase enabled estimation of associations across a large sample, while the qualitative phase provided interpretive depth. The study adopted a pragmatist stance, recognising that quantitative and qualitative approaches offer complementary but partial perspectives on the phenomena under investigation (Morgan 2014). The qualitative phase was designed specifically to explain quantitative patterns, particularly the sources of programme-level variation and the contextual mechanisms underlying the observed associations; participant selection for this phase was therefore informed directly by the quantitative results.

Ethical considerations

Ethical approval

was obtained from the institutional review board of [name of university masked for review] (Protocol No. [masked]). All participants provided written informed consent. Participation was voluntary, and

participants were assured of anonymity, confidentiality and the right to withdraw without consequence. Participants in the interview phase gave separate written consent for audio-recording.

Quantitative phase

Setting, sampling and recruitment

The study was conducted in three provinces of Uzbekistan – Tashkent, Samarkand and Kashkadarya – selected to maximise variation in urban–rural composition, economic development and educational infrastructure. Within each province, non-formal adult education programmes were identified through the national register maintained by the Republican Centre for the Retraining and Advanced Training of Pedagogical Staff, supplemented by snowball sampling to locate community-based programmes not included in the register.

Programme selection proceeded in three stages. First, all non-formal adult education programmes in the three provinces were enumerated (N = 147). Second, programmes were retained if they (a) had operated for at least one academic year, (b) enrolled adult learners aged 18 years or older, (c) offered at least four hours of instruction per week and (d) had a minimum enrolment of 10 learners. These criteria excluded short workshops and micro-programmes with limited structured learning time, leaving 68 eligible programmes. Third, 30 programmes were selected by stratified random sampling, with stratification by province (Tashkent n = 12, Samarkand n = 10, Kashkadarya n = 8) and programme type (literacy n = 8, vocational skills n = 10, civic education n = 6, digital skills n = 6). The four types represent the principal categories of non-formal adult education provision in Uzbekistan. Four selected programmes declined to participate for administrative reasons, yielding a final sample of 26 programmes.

All adults enrolled in the selected programmes were eligible. Facilitators distributed information sheets and consent forms during regular sessions. Of 412 eligible learners, 324 returned consent forms (response rate 78.6%). Twelve were excluded because more than 20% of survey items were missing, yielding a final quantitative sample of 312 learners. The sample comprised 168 women (53.8%) and 144 men (46.2%), with a mean age of 38.4 years (SD = 11.7, range 18–67). Most participants held a secondary school certificate (59.3%); 18.3% had not completed secondary education and 22.4% held a tertiary qualification (Table 1).

Table 1
Sample characteristics (*N* = 312).

Characteristic	*n*	%
Gender		
Female	168	53.8
Male	144	46.2
Age group		
18–30 years	98	31.4
31–45 years	124	39.7
46–60 years	76	24.4
61 years and over	14	4.5
Educational attainment		
Incomplete secondary	57	18.3
Secondary certificate	185	59.3
Tertiary qualification	70	22.4
Programme type		
Literacy	74	23.7
Vocational skills	108	34.6
Civic education	66	21.2
Digital skills	64	20.5
Location		
Urban	186	59.6
Rural	126	40.4
Province		
Tashkent	142	45.5
Samarkand	98	31.4
Kashkadarya	72	23.1

Non-response analysis

To assess potential non-response bias, participants included in the analysis (n = 312) were compared with the remaining eligible learners (n = 100; 88 who did not return consent forms and 12 excluded for missing data) using available administrative data. There were no statistically significant differences in gender ($\chi^2(1) = 0.42$, $p = .517$), mean age ($t(410) = 0.87$, $p = .384$) or programme type ($\chi^2(3) = 2.11$, $p = .549$). Although these results cannot rule out non-response bias on unobserved characteristics, they suggest that participants did not differ systematically from non-participants on observable characteristics.

Instruments and measures

The survey instrument was developed in four stages: (1) review of existing validated instruments; (2) expert review by a panel of five adult education researchers and practitioners from Uzbekistan and Kazakhstan; (3) cognitive pre-testing with 12 adult learners not included in the main sample, using think-aloud protocols to assess item comprehension; and (4) a pilot administration (n = 45) to generate preliminary psychometric data.

The final instrument comprised five sections. Section 1 collected demographic and background information. Section 2 assessed digital access and ownership (eight items). Section 3 measured the frequency and nature of digital technology use for learning (12 items rated on a 5-point scale from 1 = *never* to 5 = *very frequently*), adapted from the Technology Use in Learning Scale (Smith and Hayes 2017). Section 4 measured cognitive engagement with 10 items rated on a 5-point scale, adapted for adult education contexts from the engagement literature (Fredricks *et al.* 2004). Section 5 measured perceived learning effectiveness using a scale developed for this study following established guidelines for scale development (DeVellis 2017).

Construct validity and reliability

Construct validity was assessed through confirmatory factor analysis (CFA) with maximum likelihood estimation in Mplus version 8.8 (Muthén and Muthén 1998–2017). For the digital technology use scale, a one-factor model showed acceptable fit: $\chi^2(54) = 89.31$, $p = .002$, CFI = .96, TLI = .95, RMSEA = .046 (90% CI [.029, .062]), SRMR = .048. The one-factor cognitive engagement model also fitted acceptably: $\chi^2(35) = 62.47$, $p = .003$, CFI = .97, TLI = .96, RMSEA = .050 (90% CI [.030, .069]), SRMR = .044.

For the perceived learning effectiveness scale, an initial pool of 16 items was generated from the literature and expert consultation. Exploratory factor analysis of the pilot data (n = 45) identified a unidimensional structure in which eight items loaded above .50 on a single factor. CFA in the main sample confirmed acceptable fit: $\chi^2(20) = 38.92$, $p = .007$, CFI = .97, TLI = .95, RMSEA = .055 (90% CI [.028, .080]), SRMR = .039, with standardised loadings between .58 and .78. The full item wording is provided in the supplementary material.

Internal consistency was assessed with Cronbach's α and McDonald's ω: digital technology use, α = .84, ω = .85; cognitive engagement, α = .82, ω = .83; perceived learning effectiveness, α = .80, ω = .81. All values exceeded the conventional threshold of .70 (Nunnally and Bernstein 1994).

Analytic strategy

Preliminary analyses examined missing data, outliers, distributional properties and bivariate correlations. Intraclass correlation coefficients (ICCs) of .18 for cognitive engagement and .17 for perceived learning effectiveness indicated that a meaningful proportion of variance lay between programmes, justifying multilevel modelling (Hox *et al.* 2018).

Two-level random-intercept models were estimated in Mplus 8.8, with learners (Level 1) nested within programmes (Level 2). Continuous predictors were grand-mean centred. The full model took the form:

$$Y_{ij} = \gamma_{00} + \gamma_{01}(\text{Programme type})_j + \gamma_{10}(\text{Digital use})_{ij} + \Sigma\gamma(\text{Controls})_{ij} + u_{0j} + r_{ij}$$

where Y_{ij} is the outcome for learner i in programme j, γ_{00} is the overall intercept, γ_{01} represents the programme-type effects, γ_{10} is the fixed effect of digital technology use, $\Sigma\gamma(\text{Controls})_{ij}$ denotes the individual-level control variables (age, gender, educational attainment and urban–rural location), u_{0j} is the programme-level random effect and r_{ij} is the individual-level residual. Models were built sequentially: Model 1 included the control variables and programme type, and Model 2 added digital technology use. Full information maximum likelihood (FIML) estimation was used to handle missing data.

Normality of residuals was evaluated with Q–Q plots and the Shapiro–Wilk test, and homoscedasticity through residual plots. Variance inflation factors were all below 2.5, indicating no serious multicollinearity. Nested models were compared using the deviance statistic and information criteria (AIC, BIC).

Qualitative phase

Participant selection

The qualitative phase was designed to explain (a) the sources of programme-level variation identified through the ICCs and random effects, (b) the mechanisms through which digital technology use might relate to engagement and perceived effectiveness and (c) the reasons for non-significant associations in the quantitative analysis. Twenty-two adult learners were selected purposively from the survey sample, drawn from programmes in all three provinces and all four programme types. Selection criteria derived directly from the quantitative results: participants were chosen to represent variation in (1) digital technology use (high, moderate and low scores), (2) programme type, (3) province, (4) urban–rural location and (5) the magnitude and direction of their residuals from the multilevel models, that is, learners whose outcomes were better or worse than predicted. This strategy ensured that the qualitative data could illuminate quantitative patterns rather than merely illustrate them.

In addition, two programme facilitators were interviewed to provide institutional perspectives on the factors shaping digital technology use in their programmes. Their inclusion was specified in the research

protocol approved by the ethics committee. Facilitator interviews complemented learner accounts by supplying programme-level contextual information to which learners might not have access.

Data collection

Semi-structured interviews were conducted between March and May 2024 by the author, who is trained in qualitative research and fluent in Uzbek and Russian. The interview guide addressed three domains: (1) participants' experiences of using digital technologies for learning; (2) perceived facilitators of and barriers to effective digital learning; and (3) the role of institutional and social factors in shaping engagement. Probes were used to elicit specific examples and to explore emergent issues. Interviews lasted 45–90 minutes and were audio-recorded with consent.

Interviews were conducted in the participant's preferred language: 18 in Uzbek, four in Russian and two in both languages. Recordings were transcribed verbatim by a professional transcriber and checked for accuracy by the author. Russian-language transcripts were translated into Uzbek by a certified translator; a random 20% sample was back-translated to verify accuracy, and discrepancies were resolved through discussion between the translator and the author. Excerpts reported in this article were translated into English by [translator to be specified].

Qualitative analysis

Data were analysed using reflexive thematic analysis following Braun and Clarke's (2022) six phases: familiarisation, coding, generating initial themes, reviewing themes, defining and naming themes, and writing up. This approach was chosen because it emphasises the researcher's active interpretive role and is compatible with the study's pragmatist stance. The author conducted the primary coding. To support analytic reflexivity, a second researcher independently coded a random 25% of transcripts; codes were compared (87% agreement at code level) and differences were discussed with reference to the relevant transcript segments. Consistent with reflexive thematic analysis, this procedure served as a means of challenging and refining interpretations rather than as a claim to objectivity (Braun and Clarke 2022). The thematic structure was refined through iterative discussion.

Integration of the quantitative and qualitative phases

Integration occurred at three points: (1) the interview guide was developed from the quantitative results; (2) qualitative participants were selected on the basis of quantitative patterns; and (3) findings were merged in a joint display (Fetters *et al.* 2013) that juxtaposes each quantitative result with the corresponding qualitative interpretation, enabling meta-inferences across both data sources (Table 4). Qualitative findings were used to elaborate and contextualise the quantitative associations, not to establish statistical mediation or causality.

Results

Descriptive statistics and bivariate correlations

Table 2 presents means, standard deviations and bivariate correlations. Digital technology use was moderate across the sample (M = 2.94, SD = 0.87, range 1–5). Mean cognitive engagement was 3.21 (SD = 0.79) and mean perceived learning effectiveness was 3.15 (SD = 0.82). Digital technology use correlated positively with cognitive engagement (r = .52, p < .001) and perceived learning effectiveness (r = .48, p < .001).

Digital technology use differed significantly by programme type ($F(3, 308) = 14.3$, p < .001, η^2 = .12): participants in digital skills programmes reported higher use (M = 4.12, SD = 0.61) than those in literacy programmes (M = 2.31, SD = 0.79). Urban participants reported higher use than rural participants ($t(310) = 6.87$, p < .001, d = 0.78). Age correlated moderately and negatively with digital technology use (r = − .32, p < .001). Gender differences in digital technology use were small and non-significant after controlling for age and location (β = .05, p = .312).

Table 2
Means, standard deviations and bivariate correlations among study variables.

Variable	*M*	*SD*	1	2	3	4	5	6
1. Age	38.4	11.7	–					
2. Gender (male = 1)	0.46	0.50	−.04	–				
3. Education	2.04	0.65	−.22**	.08	–			
4. Urban (urban = 1)	0.60	0.49	−.15*	.06	.18**	–		
5. Digital use	2.94	0.87	−.32**	.05	.24**	.35**	–	
6. Cognitive engagement	3.21	0.79	−.18**	.07	.26**	.30**	.52**	–
7. Perceived effectiveness	3.15	0.82	−.14*	.04	.22**	.27**	.48**	.62**

Note. N = 312. Education coded 1 = incomplete secondary, 2 = secondary, 3 = tertiary. Gender coded 0 = female, 1 = male. Location coded 0 = rural, 1 = urban. *p < .05. **p < .01.

Multilevel models

Table 3 presents the multilevel models for both outcomes. The unconditional models confirmed significant programme-level variance, with ICCs of .18 for cognitive engagement and .17 for perceived learning effectiveness; that is, 18% and 17% of the variance in the respective outcomes lay between programmes.

Model 1 included the Level 1 control variables (age, gender, educational attainment and urban–rural location) and programme type at Level 2. Programme type was a significant predictor of both outcomes. Relative to literacy programmes (reference category), vocational (β = .31, p < .001), civic education (β = .18, p = .012) and digital skills programmes (β = .42, p < .001) showed higher mean cognitive engagement. A similar pattern was observed for perceived learning effectiveness.

Table 3
Two-level random-intercept models predicting cognitive engagement and perceived learning effectiveness.

Intercept	**CE M1**	**CE M2**	**CE M3**	**PLE M1**	**PLE M2**	**PLE M3**
	2.98* **	**2.85*** **	**1.92*** **	**2.92*** **	**2.79*** **	**1.88*** **
	(0.12)	(0.11)	(0.18)	(0.13)	(0.12)	(0.19)
Level 1						
Age	−.13*	−.12*	−.11*	−.10	−.09	−.09
	(0.06)	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)
Gender (male)	.07	.06	.06	.05	.05	.05
	(0.08)	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)
Education	.24***	.23***	.22***	.21***	.20***	.19**
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Urban	.19**	.17**	.16**	.17**	.15*	.14*
	(0.07)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
Digital use		.38***	.38***		.35***	.35***
		(0.05)	(0.05)		(0.06)	(0.06)
Level 2						
Vocational	.31***	.28***	.26***	.29***	.26***	.24***
Civic education	.18*	.16*	.15*	.16*	.14*	.13
Digital skills	.42***	.38***	.36***	.40***	.36***	.34***
Random effects						
σ^2 programme	0.12	0.09	0.08	0.11	0.08	0.07
σ^2 individual	0.55	0.48	0.48	0.58	0.51	0.51
ICC	.18	.16	.14	.17	.14	.12
Deviance	1892	1848	1836	1942	1898	1886
AIC	1906	1866	1856	1956	1916	1906

Note. *N* = 312 learners nested in 26 programmes. CE = cognitive engagement; PLE = perceived learning effectiveness. Standard errors in parentheses. Continuous predictors grand-mean centred. Reference category for programme type = literacy. Coefficients reported as β. *p < .05. **p < .01. ***p < .001.

Model 2 added digital technology use as the focal predictor. For cognitive engagement, digital technology use was a significant positive predictor (β = .38, 95% CI [.27, .49], $p < .001$). Adding digital technology use reduced programme-level variance by approximately 31%, suggesting that between-programme differences in average digital technology use partly accounted for programme-level variation in cognitive engagement. Among the control variables, educational attainment (β = .22, $p < .001$) and urban location (β = .16, $p = .004$) were significant positive predictors. Age showed a small negative association (β = −.11, $p = .032$), and gender was not a significant predictor (β = .06, $p = .241$).

For perceived learning effectiveness, digital technology use was again a significant positive predictor (β = .35, 95% CI [.24, .46], $p < .001$), and its inclusion reduced programme-level variance by approximately 29%. Educational attainment (β = .19, $p = .001$) and urban location (β = .14, $p = .008$) were significant, whereas age (β = −.09, $p = .072$) and gender (β = .05, $p = .318$) were not.

The addition of digital technology use reduced the deviance for both outcomes relative to Model 1. For the final cognitive engagement model, AIC = 1,842.3 and BIC = 1,876.5; for the final perceived learning effectiveness model, AIC = 1,891.7 and BIC = 1,925.9. Q–Q plots and residual diagnostics indicated no substantial violations of the normality or homoscedasticity assumptions.

Qualitative findings

Reflexive thematic analysis of the 24 interview transcripts (22 learners, two facilitators) generated four themes that elaborate and contextualise the quantitative findings: (1) digital self-efficacy as a dynamic, socially produced attribute; (2) peer-mediated social learning; (3) institutional culture as an enabling or constraining force; and (4) the persistence of structural barriers. Table 4 integrates the quantitative and qualitative findings.

Table 4
Joint display of quantitative and qualitative findings.

Quantitative finding	Qualitative elaboration
Digital use associated with engagement (β = .38) and perceived effectiveness (β = .35)	Digital self-efficacy develops through supported practice; peer learning amplifies individual technology use (Themes 1 and 2)
Programme-level ICC = .17–.18	Programmes differ in institutional support: some encourage digital integration, others discourage it (Theme 3)
Programme type significant	Digital skills programmes integrate technology coherently; literacy programmes often lack infrastructure (Theme 3)
Urban location significant	Electricity, network coverage and data costs constrain rural learners' engagement (Theme 4)
Age negatively associated (small effect)	Older learners describe initial anxiety but develop competence with scaffolded support (Theme 1)
Gender not significant	Women and men describe similar barriers and facilitators

Theme 1: Digital self-efficacy as dynamic and socially produced

The association between digital technology use and the two outcomes was illuminated by accounts that described digital self-efficacy not as a fixed trait but as an attribute that develops through social experience. Participants consistently described trajectories from initial anxiety to emerging competence, catalysed by facilitator support and peer encouragement. A learner in a rural literacy programme described this trajectory:

I was afraid of computers at first. I thought they were for young people, for educated people. But my instructor showed me step by step, and I realised I could do things I never imagined. (Female, 44, rural literacy programme, Kashkadarya)

Participants who reported the greatest gains in confidence typically identified specific supportive interactions – with facilitators or more confident peers – as turning points. A facilitator offered an institutional perspective:

We see learners come in who have never touched a smartphone for learning. Within two months, some of them are teaching others. But this only happens when we create the space for it – when they feel safe to try and fail. (Facilitator, vocational programme, Tashkent)

These accounts suggest that the association between digital technology use and engagement may operate partly through the development of digital self-efficacy in supported practice, although the cross-sectional design does not permit formal tests of mediation.

Theme 2: Peer-mediated social learning

Participants repeatedly emphasised peer interaction as a key means of acquiring digital skills and consolidating learning. This theme suggests that digital technology use in these programmes was rarely an individual activity; rather, it was embedded in social practices that extended its reach.

The official programme is just two hours a week. But we're actually learning all the time through the group – sharing things we found online, helping each other understand them. The WhatsApp group is where the real learning happens. (Male, 29, vocational programme, Samarkand)

Participants described several collaborative practices: pooling mobile data allowances for group research, creating informal WhatsApp groups to continue discussions outside programme time and establishing peer tutoring between more and less digitally confident learners.

Theme 3: Institutional culture as enabler or constraint

The programme-level variance identified in the multilevel models (ICC = .17–.18) was illuminated by accounts revealing marked differences in institutional support for digital technology use. This theme helps explain why learners in different programmes reported different levels of engagement and perceived effectiveness after individual characteristics were controlled for. Participants in programmes with a dedicated digital component described purposeful integration of technology into learning activities. In contrast, participants in literacy and some civic education programmes frequently reported institutional ambivalence or discouragement. One facilitator had been told informally that mobile phones should be put away during sessions 'because they are a distraction', even though participants used them to access programme-related resources. Such norms can directly undermine the learning potential of digital technology use.

Theme 4: Navigating structural barriers

The fourth theme contextualises the finding that urban location predicted engagement and perceived effectiveness. Participants described a persistent tension between enthusiasm for digital learning and structural barriers to realising it. Financial barriers – the cost of mobile data and of device repair or replacement – were cited consistently, as were unreliable electricity in rural areas and poor mobile network coverage.

I want to learn. I have the phone, I have the will. But when the electricity is out for two days, or when I cannot afford data this month – what can I do? The desire alone is not enough. (Female, 38, rural vocational programme, Kashkadarya)

This account resonates with the capability approach's argument that resources and aspiration, without adequate conversion conditions, do not amount to genuine capability (Sen 1999). The urban–rural difference observed in the quantitative analysis appears to reflect such structural conditions rather than differences in learners' motivation or capacity.

Discussion

This study examined the association between digital technology use and two proximal indicators of learning processes among adults in non-formal education programmes in Uzbekistan. By modelling the nesting of learners within programmes and integrating the quantitative results with qualitative inquiry, it provides methodologically transparent and contextually situated evidence from an under-researched region. The discussion is organised around the three research questions.

Digital technology use and proximal learning indicators (RQ1)

Digital technology use was a statistically significant positive predictor of both cognitive engagement (β = .38) and perceived learning effectiveness (β = .35) after demographic characteristics and programme type were controlled for. This pattern is consistent with meta-analytic evidence from other regions (Tamim *et al.* 2011, Means *et al.* 2013). The associations are moderate in size, and their consistency across both outcomes lends confidence to their robustness.

It is essential to be clear about what this finding does and does not show. The cross-sectional design precludes causal inference. The associations may reflect an influence of digital technology use on engagement and perceived effectiveness, but they are equally consistent with reverse causation (more engaged learners may seek out digital tools) and with omitted-variable bias (unmeasured characteristics may shape both). Throughout this article, the term ‘predictor’ refers to statistical association within a cross-sectional model, not to a demonstrated effect.

Individual and programme-level variation (RQ2)

Educational attainment and urban location were positively associated with both outcomes, whereas the negative association with age was small and significant only for cognitive engagement. The finding that 17–18% of the variance in both outcomes lay at the programme level is an important contribution. It indicates that programme context – facilitator practices, institutional culture and peer dynamics – shapes learner engagement over and above individual characteristics. Programme type reduced but did not eliminate this between-programme variance, suggesting that relevant programme-level factors extend beyond type. The qualitative findings point to institutional culture and peer learning norms as candidate factors, although testing specific programme-level hypotheses would require a larger sample of programmes.

Contextual mechanisms (RQ3)

The qualitative findings suggest plausible contextual mechanisms behind the quantitative associations. The emergence of digital self-efficacy as a dynamic attribute shaped by facilitator support and peer modelling is consistent with social cognitive theory (Bandura 1997). The qualitative data illuminate

possible mechanisms; they do not establish mediation in the statistical sense, which would require longitudinal data and appropriate analytic techniques (Hayes 2018).

The centrality of peer-mediated learning in participants' accounts challenges the individualistic assumptions implicit in much of the digital learning literature. The informal learning communities described – WhatsApp groups, peer instruction and shared data arrangements – are consistent with activity theory's emphasis on community and division of labour (Engeström 1987) and with evidence from non-formal digital training in Europe, where the benefits of participation have been documented from the perspectives of learners, peer tutors and teachers alike (Pihlainen *et al.* 2021). Programme designs that create structured opportunities for peer interaction may therefore be more effective than designs that position learners as isolated individuals.

Theoretical contributions

The study makes three theoretical contributions. First, it extends self-directed learning theory to an under-researched transitional context and shows that the conditions supporting self-direction – particularly peer learning and facilitator scaffolding – matter alongside individual learner characteristics. This qualifies individualistic readings of self-directed learning and supports Garrison's (1997) view of self-direction as socially situated.

Second, the study advances capability-based analyses of adult education by showing that digital access alone is insufficient and that institutional culture and structural equity are conditions for converting resources into learning opportunities. Participants who were unable to benefit from available digital resources because of infrastructural and financial constraints illustrate Sen's (1999) distinction between resources and capabilities.

Third, the study contributes methodologically to adult education research. By showing that a meaningful proportion of variance in engagement and perceived effectiveness lies at the programme level, it underlines the importance of analytic techniques that account for nested data – a consideration frequently overlooked in a field where learners are routinely nested within programmes, institutions or localities.

Implications for policy and practice

For policymakers in Uzbekistan and comparable transitional settings, investment in digital infrastructure is necessary but insufficient. Equal attention should be given to facilitator professional development, structured peer learning, affordable data access and programme cultures that actively support digital tool use. Because programme-level factors account for 17–18% of the variance in the engagement indicators, institutional interventions may have meaningful effects at scale.

For programme designers, the findings highlight the importance of building social infrastructure alongside technical infrastructure. The peer learning practices described by participants emerged informally rather than by design; formalising and supporting such practices may extend their reach. For

facilitators, the findings underline the role of supportive scaffolding in developing digital self-efficacy, particularly among older and less formally educated learners.

Limitations and directions for future research

Several limitations must be acknowledged. First, the cross-sectional design precludes causal inference; longitudinal designs are needed to establish temporal order and to permit formal mediation analysis. Second, reliance on self-reported measures, particularly for perceived learning effectiveness, introduces potential bias from social desirability and subjective interpretation, and objective measures of learning achievement were not available. Third, the three provinces, although varied, do not represent all regions of Uzbekistan, and the findings should be generalised with caution. Fourth, the qualitative sample of 22 learners and two facilitators was judged adequate in terms of information power (Malterud *et al.* 2016) for the study's focused explanatory aim, but it cannot capture the full diversity of programme contexts. Fifth, the perceived learning effectiveness scale was developed for this study and requires validation in independent samples. Finally, facilitator accounts are not directly comparable with learner accounts; they were therefore analysed with attention to the different positions from which they were given.

Future research should track digital technology use and learning indicators longitudinally, incorporate objective measures of learning alongside self-reports and use larger samples of programmes to estimate programme-level effects more precisely. Comparative studies across Central Asian countries could clarify the role of national policy, and intervention studies could test the effects of structured peer learning and facilitator development.

Conclusion

This study examined the association between digital technology use and two proximal indicators of learning processes – cognitive engagement and perceived learning effectiveness – among adults in non-formal education programmes in Uzbekistan. Using a sequential explanatory mixed-methods design with multilevel modelling, it found that digital technology use was positively associated with both outcomes at the individual level, while 17–18% of the variance in each outcome lay at the programme level. Qualitative findings identified contextual mechanisms – the development of digital self-efficacy, peer-mediated learning, institutional culture and structural barriers – that may explain these associations.

The study contributes evidence from an under-researched Central Asian context, demonstrates the value of multilevel approaches in adult education research and shows the socially embedded nature of digital learning among adults in a transitional economy. For policy and practice, the findings argue for equity-focused institutional investment that extends beyond digital infrastructure to the social and pedagogical conditions under which technology can realise its educational potential.

Declarations

Author Contribution

DB asosiy qo'lyozma matnini yozgan

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