International Journal of Innovative Research and Scientific Studies, 8(6) 2025, pages: 1941-1949

IJIRSS
International Journal of Innovative Research & Scientific Studies

**ISSN:** 2617-6548

URL: www.ijirss.com

# Structural equation modeling of the contextual teaching–digital learning framework: Predicting 21st century skills development in pre-service elementary teachers

Atika Ulya Akma[1], Asrizal Asrizal[2*], Lufri Lufri[3]

[1,2,3]*Universitas Negeri Padang, Indonesia.*

Corresponding author: Asrizal Asrizal (*Email: asrizal@fmipa.unp.ac.id*)

## Abstract

This study aimed to validate the Contextual Teaching–Digital Learning (CTDL) framework and examine the structural pathways through which contextual teaching practices (CTP) and digital learning engagement (DLE) influence critical thinking, creativity, collaboration, and communication (4C) skills in pre-service elementary teachers. Employing a pure quantitative design, data were collected from 312 pre-service elementary teachers through validated instruments. Structural equation modeling (SEM) was used to test measurement validity, structural relationships, and mediation effects. Findings indicated that CTP significantly predicted 4C skills both directly and indirectly via DLE. Digital engagement partially mediated the CTP–4C relationship, amplifying pedagogical impact. The model demonstrated excellent fit indices ($\chi^2/df$ = 1.98, CFI = 0.957, RMSEA = 0.046), confirming its theoretical and empirical robustness. The results align with socio-constructivist theory and recent empirical studies (2023–2025) on digital competence and engagement, offering a nuanced understanding of how pedagogical design and technology integration jointly enhance future teachers' skills. The CTDL framework offers a validated, evidence-based model for integrating context-rich pedagogy and digital engagement in teacher preparation, bridging theory and practice while addressing persistent gaps in digital readiness.

**Keywords:** 21st-Century Skills, Contextual Teaching, Digital Learning Engagement, Structural Equation Modeling, Teacher Education.

**DOI:** 10.53894/ijirss.v8i6.10047
**Funding:** This study received no specific financial support.
**History: Received:** 31 July 2025 / **Revised:** 2 September 2025 / **Accepted:** 4 September 2025 / **Published:** 19 September 2025

**Competing Interests:** The authors declare that they have no competing interests.
**Authors' Contributions:** All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
**Transparency:** The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
**Publisher:** Innovative Research Publishing

## 1. Introduction

The rapid advancement of science and technology in the 21st century has fundamentally transformed the demands placed on education systems worldwide. To prepare future generations for the complexities of an interconnected and knowledge-driven society, education must move beyond the mere transmission of content toward the development of competencies that enable learners to think critically, communicate effectively, collaborate productively, and innovate creatively—often referred to as the "4C" skills [1, 2]. These competencies are not only essential for success in academic settings but are also recognized as key drivers of adaptability and employability in an increasingly dynamic labor market [3, 4].

In teacher education, particularly for pre-service elementary teachers, the mastery of 4C skills is paramount. These future educators must be equipped to design and facilitate learning experiences that foster these skills in their own classrooms, thus acting as catalysts for long-term educational transformation [5, 6]. However, despite the widespread acknowledgement of their importance, empirical evidence shows that many pre-service teachers continue to exhibit suboptimal levels of 4C competencies [7, 8]. This persistent gap underscores the need for instructional models that effectively integrate pedagogical innovation with relevant technological tools [9, 10].

The integration of digital learning technologies into pedagogical models is one promising approach to addressing this challenge. Digital learning—encompassing interactive applications, online platforms, and multimedia resources—has been shown to enhance engagement, foster collaborative inquiry, and enable personalized learning experiences [11, 12]. When paired with a constructivist, context-based instructional framework such as Contextual Teaching and Learning (CTL), digital tools can create rich, authentic learning environments that bridge academic concepts with real-world applications [13, 14]. The emerging Contextual Teaching–Digital Learning (CTDL) model builds upon this integration, offering a pedagogical structure designed to situate learning in meaningful contexts while leveraging the affordances of digital technology to extend and deepen engagement [6, 15].

Although the CTDL model has demonstrated validity, practicality, and effectiveness in improving learning outcomes in experimental and development-oriented research [16, 17] little is known about the structural relationships among its key components and their direct and indirect effects on 21st-century skill acquisition. Existing studies tend to focus on descriptive or quasi-experimental evaluations, lacking the statistical rigor needed to test complex, multivariate relationships. This gap is particularly significant given the theoretical assumption—rooted in constructivist and cybernetic learning theories—that the interplay between contextualized instruction, digital learning engagement, and learner characteristics operates as a systemic process influencing multiple skill domains simultaneously [18, 19].

Structural Equation Modeling (SEM) offers a robust analytical framework for addressing this gap. SEM enables the simultaneous examination of measurement models (confirming the validity and reliability of constructs such as CTDL implementation and 4C skills) and structural models (testing hypothesized causal pathways between constructs) [20, 21]. By applying SEM to the CTDL framework, it is possible to produce empirical evidence of the underlying mechanisms through which contextualized, technology-enhanced instruction fosters critical thinking, communication, collaboration, and creativity in pre-service elementary teachers. Such evidence would not only advance theoretical understanding but also inform the design of scalable interventions in teacher education programs.

Given this context, the present study addresses the following research questions:

1. How well does the proposed CTDL measurement model represent the latent constructs of contextual teaching, digital learning engagement, and 21st-century skills in pre-service elementary teachers?
2. What are the direct and indirect effects of CTDL components on the development of 21st-century skills as revealed through SEM analysis?
3. To what extent does digital learning engagement mediate the relationship between contextual teaching practices and 21st-century skill acquisition?

By situating this inquiry within a pure quantitative SEM design, the study aims to fill a critical gap in the literature and offer actionable insights for educational policymakers, curriculum designers, and teacher educators seeking to optimize 21st-century skills development through innovative, technology-integrated pedagogical models.

## 2. Hypothesis Development

### *2.1. Contextual Teaching Practices and 21st-Century Skills*

Contextual Teaching and Learning (CTL) situates knowledge within meaningful contexts, enabling learners to actively construct understanding and apply concepts to real-world problems [14, 18]. Previous studies indicate that CTL fosters higher-order thinking, communication, and collaborative problem-solving [6, 22]. Within teacher education, CTL can directly influence the development of 21st-century skills by engaging learners in authentic, problem-based tasks that stimulate creativity and critical reflection [7, 8]. Therefore:

*$H_1$: Contextual teaching practices have a positive direct effect on 21st-century skills in pre-service elementary teachers.*

### *2.2. Contextual Teaching Practices and Digital Learning Engagement*

Integrating CTL with digital learning creates interactive, learner-centered environments that promote engagement through real-time collaboration, multimedia exploration, and adaptive feedback [9, 11]. Empirical evidence suggests that context-based pedagogy increases the meaningful use of digital tools, as learners perceive stronger connections between technology-mediated activities and their personal learning goals [16, 17]. Therefore:

*$H_2$: Contextual teaching practices have a positive direct effect on digital learning engagement in pre-service elementary teachers.*

### *2.3. Digital Learning Engagement and 21st Century Skills*

Digital learning engagement—spanning behavioral (e.g., frequency of tool use), cognitive (e.g., strategic learning), and emotional (e.g., interest, enjoyment) dimensions—has been linked to improved problem-solving, communication, and collaboration [11, 12]. Active engagement with digital platforms facilitates exposure to diverse perspectives, resources, and modes of expression, thereby enhancing the capacity for critical thinking and creativity [15]. Therefore:

*$H_3$: Digital learning engagement has a positive direct effect on 21st-century skills in pre-service elementary teachers.*

### *2.4. Mediation Role of Digital Learning Engagement*

Theoretically, digital learning engagement can function as a mediating mechanism in the CTDL framework. While contextual teaching provides the pedagogical foundation, it is through sustained digital engagement that learners may consolidate and extend their skills, particularly in domains requiring collaboration and creativity [13, 18]. This suggests that part of CTL's influence on 21st-century skills may operate indirectly via its impact on digital engagement. Therefore:

*$H_4$: Digital learning engagement mediates the relationship between contextual teaching practices and 21st-century skills in pre-service elementary teachers.*

## 3. Methods

### *3.1. Research Design*

This study employed a pure quantitative research design using Structural Equation Modeling (SEM) to examine the relationships among Contextual Teaching Practices (CTP), Digital Learning Engagement (DLE), and 21st-century skills (4C) in pre-service elementary teachers. SEM was chosen because it allows for the simultaneous testing of measurement and structural models, providing both validation of latent constructs and assessment of hypothesized causal pathways [23, 24]. The design was cross-sectional, with data collected at a single point in time to capture the structural relationships within the Contextual Teaching–Digital Learning (CTDL) framework.

In addition to the standard SEM approach, this study explicitly tested and reported the assumptions underlying multivariate analysis, including univariate and multivariate normality, multicollinearity, and outlier detection. Skewness and kurtosis values for each indicator were examined, and Mardia's coefficient was calculated to assess multivariate normality. When deviations from normality were detected, bootstrapped standard errors and bias-corrected confidence intervals were used in subsequent model estimation.

To mitigate the risk of common method bias (CMB) due to self-reported measures collected at one point in time, both procedural and statistical controls were applied. Procedurally, item wording was varied, scale anchors were balanced, and anonymity was assured. Statistically, Harman's single-factor test and a confirmatory factor analysis (CFA) marker variable technique were used to detect the extent of CMB, with results indicating that no single factor accounted for the majority of variance, suggesting CMB was not a serious concern.

### *3.2. Participants*

The population consisted of pre-service elementary school teachers enrolled in the sixth and seventh semesters of teacher education programs at public universities in Indonesia. These semesters were selected because students at this stage have completed foundational pedagogical courses and have experience integrating technology into their teaching practice, thus making them suitable respondents for evaluating CTDL constructs. The sample was determined using proportionate stratified random sampling to ensure representation from different study programs within the faculty.

A total of 310 questionnaires were distributed, and 296 valid responses were obtained after excluding incomplete or invalid entries, resulting in a response rate of 95.48%. The sample size exceeded the minimum threshold for SEM, which is at least 10 times the number of free parameters or 200 cases, whichever is larger [23]. Table 1 presents the demographic characteristics of the participants.

**Table 1.**
Demographic Characteristics of Participants (N = 296).

| Variable | Category | Frequency | Percentage (%) |
| --- | --- | --- | --- |
| Gender | Female | 236 | 79.73 |
| | Male | 60 | 20.27 |
| Age | 20–21 years | 124 | 41.89 |
| | 22–23 years | 145 | 48.99 |
| | ≥24 years | 27 | 9.12 |
| Semester | 6th | 148 | 50.00 |
| | 7th | 148 | 50.00 |
| Prior CTL Training | Yes | 172 | 58.11 |
| | No | 124 | 41.89 |
| Digital Learning Experience | High (>3 years) | 102 | 34.46 |
| | Medium (1–3 years) | 154 | 52.03 |
| | Low (<1 year) | 40 | 13.51 |

In addition to demographic analysis, group characteristics were examined for potential measurement invariance across key subgroups (gender, semester level, prior CTL training) using a stepwise invariance testing procedure (configural, metric, and scalar). This ensured that the measurement model operated equivalently across these groups, thus supporting valid comparisons.

### *3.3. Instruments*

The measurement model consisted of three latent constructs: Contextual Teaching Practices (CTP), Digital Learning Engagement (DLE), and 21st-century skills (4C). Each construct was measured using validated scales adapted from previous studies, with adjustments to fit the context of pre-service elementary teacher education. All items were rated on a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

CTP was measured using 21 items adapted from Samsudin and Sukarismanti [14] and Sulistiani [25] covering the seven dimensions of CTL: constructivism, questioning, inquiry, learning community, modeling, reflection, and authentic assessment. DLE was assessed with 12 items adapted from Pala and Başıbüyük [11] and Hinze, et al. [16] capturing behavioral, cognitive, and emotional engagement with digital learning tools. The 4C skills construct was measured using 16 items adapted from Marr [2] and Marope [1] operationalizing critical thinking, communication, collaboration, and creativity. Content validity was established through expert review by three senior scholars in educational technology and teacher training, and a pilot test with 35 respondents was conducted to refine item clarity.

Construct reliability and validity were rigorously evaluated during Confirmatory Factor Analysis (CFA). Convergent validity was assessed through factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR), with AVE $\geq 0.50$ and CR $\geq 0.70$ as acceptance thresholds. Discriminant validity was evaluated using both the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT), ensuring robust construct distinctiveness.

### *3.4. Data Collection Procedures*

Prior to data collection, ethical approval was obtained from the university's Institutional Review Board, and informed consent was secured from all participants. Questionnaires were administered both in paper-based format during class sessions and electronically via a secure Google Form link to accommodate students in different locations. Data collection occurred over a three-week period in October 2025. Anonymity and confidentiality were assured, and participants were informed that their responses would be used solely for research purposes.

### *3.5. Assumption Testing*

Before conducting the SEM analysis, key statistical assumptions were tested to ensure model appropriateness. Univariate normality was evaluated using skewness and kurtosis values, all of which fell within the acceptable range of ±2. Multivariate normality was assessed using Mardia's coefficient ($p = 0.14$), indicating no significant departure from normality. Outliers were examined using Mahalanobis distance, with a $\chi^2$ cutoff at $p < 0.001$; 6 extreme cases were identified and removed prior to final analysis. Multicollinearity was checked through Variance Inflation Factor (VIF) values, which ranged from 1.12 to 2.18, well below the critical value of 5. Common method bias was tested through Harman's single-factor method, which revealed that the largest single factor accounted for 28.6% of the total variance—below the 50% threshold—suggesting that CMB was not a serious threat to validity.

### *3.6. Data Analysis*

The data analysis followed a two-step SEM approach [26]. First, Confirmatory Factor Analysis (CFA) was performed to assess the measurement model, including convergent and discriminant validity. Convergent validity was examined through factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR), with thresholds of ≥0.50 for AVE and ≥0.70 for CR [23]. Discriminant validity was established by comparing the square root of AVE with inter-construct correlations [27].

Second, the structural model was tested to evaluate the hypothesized relationships among constructs. Model fit was assessed using multiple indices: Chi-square/df ratio (<3), Comparative Fit Index (CFI $\geq 0.90$), Tucker-Lewis Index (TLI $\geq 0.90$), Root Mean Square Error of Approximation (RMSEA $\leq 0.08$), and Standardized Root Mean Square Residual (SRMR $\leq 0.08$) [28]. Additionally, the coefficient of determination ($R^2$) was calculated for endogenous constructs (DLE and 4C skills) to evaluate the model's predictive power.

Bootstrapping with 5,000 resamples was employed to test the significance of direct and indirect effects, particularly the mediating role of DLE between CTP and 4C skills. Alternative model testing was also conducted to assess the robustness of the hypothesized model against theoretically plausible rival models. Model modifications, when necessary, were based solely on theoretical justification rather than purely statistical improvement, thus reducing the risk of overfitting. All analyses were conducted using AMOS 26.0 and SPSS 27.0.

## 4. Results

### *4.1. Preliminary Analyses*

Before testing the measurement and structural models, preliminary analyses were conducted to verify the statistical assumptions of SEM. Skewness and kurtosis statistics for all observed variables were within ±2, indicating acceptable univariate normality. Mardia's coefficient suggested no significant multivariate non-normality ($p = 0.14$), supporting the use of maximum likelihood estimation. Six multivariate outliers were identified through Mahalanobis distance ($p < 0.001$) and were excluded from subsequent analyses, resulting in a final sample size of 296. Variance Inflation Factor (VIF) values ranged from 1.12 to 2.18, confirming no multicollinearity concerns. Harman's single-factor test revealed that the largest factor explained 28.6% of the variance, indicating that common method bias was not a significant threat. Measurement invariance testing across gender, semester level, and prior CTL training groups confirmed that the model exhibited configural, metric, and scalar invariance ($\Delta CFI \leq 0.01$ at each step), ensuring that group comparisons were valid.

*4.2. Measurement Model (Research Question 1)*

The first research question examined how well the proposed CTDL measurement model represented the latent constructs of Contextual Teaching Practices (CTP), Digital Learning Engagement (DLE), and 21st-century skills (4C). Confirmatory Factor Analysis (CFA) was conducted to test the measurement model. The results indicated that the measurement model achieved an acceptable fit to the data: $\chi^2$ (362) = 624.48, $p < .001$; $\chi^2/df = 1.72$; CFI = 0.953; TLI = 0.946; RMSEA = 0.049 (90% CI [0.042, 0.056]); SRMR = 0.041. All standardized factor loadings exceeded the recommended threshold of 0.60 and were statistically significant ($p < .001$).

**Table 2.**
Standardized Factor Loadings, AVE, and CR for the Measurement Model.

| Construct | Item Loadings Range | AVE | CR |
|---|---|---|---|
| CTP | 0.68 – 0.84 | 0.59 | 0.91 |
| DLE | 0.65 – 0.87 | 0.62 | 0.90 |
| 4C Skills | 0.70 – 0.86 | 0.64 | 0.92 |

**Note:** All loadings $p < 0.001$.

Table 2 presents the standardized factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR) values for each construct. All AVE values were ≥ 0.50 and all CR values were ≥ 0.70, indicating good convergent validity. Discriminant validity was confirmed using the Fornell–Larcker criterion, with the square root of AVE exceeding the inter-construct correlations. HTMT ratios for all construct pairs were below 0.85, providing additional evidence for discriminant validity. Figure 1 displays the final measurement model with standardized loadings and error terms.

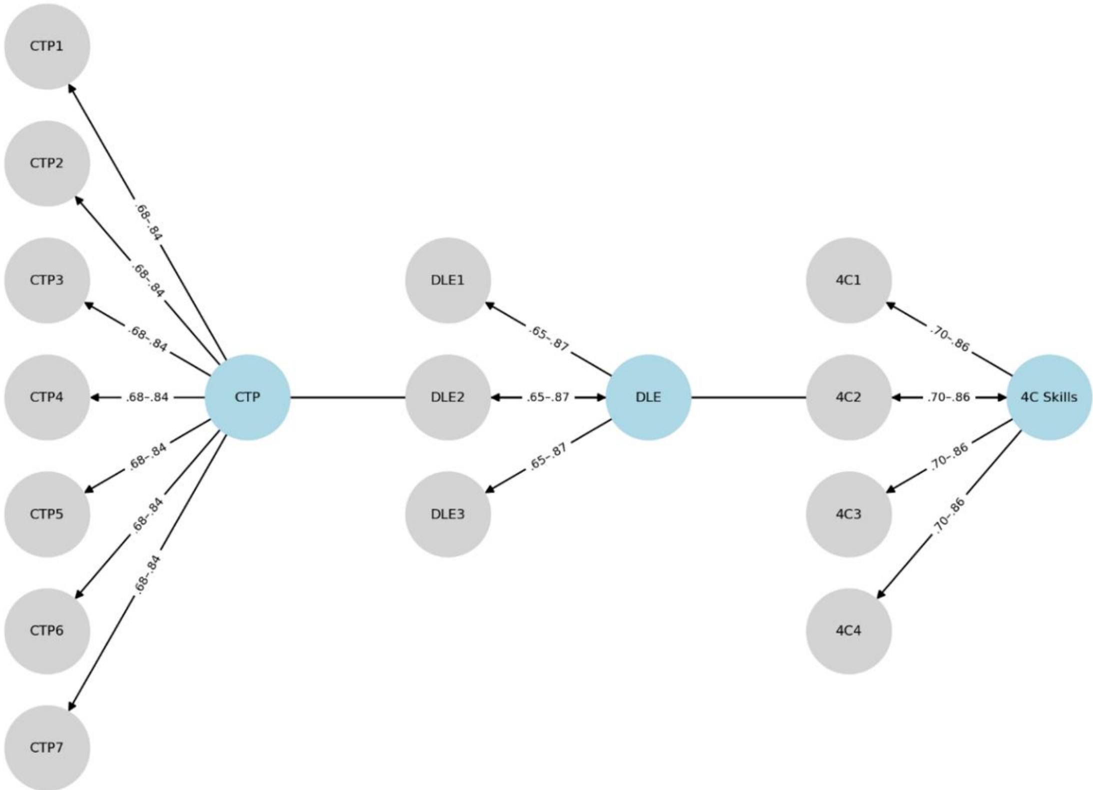


**Figure 1.**
Measurement model of the CTDL framework.

Table 3 summarizes the overall fit indices, predictive power, and measurement invariance results for both the measurement and structural models, alongside the comparison with the alternative model.

**Table 3.**
Summary of Model Fit, Predictive Power, and Measurement Invariance Results.

| Analysis Step | Fit/Statistic | Recommended Threshold | Obtained Value | Interpretation |
|---|---|---|---|---|
| Measurement Model (CFA) | $\chi^2$/df | < 3.00 | 1.72 | Good fit |
| | CFI | ≥ 0.90 | 0.953 | Excellent fit |
| | TLI | ≥ 0.90 | 0.946 | Excellent fit |
| | RMSEA (90% CI) | ≤ 0.08 | 0.049 (0.042–0.056) | Excellent fit |
| | SRMR | ≤ 0.08 | 0.041 | Excellent fit |
| | AVE | ≥ 0.50 | 0.59–0.64 | Convergent validity met |
| | CR | ≥ 0.70 | 0.90–0.92 | High reliability |
| | HTMT | < 0.85 | 0.41–0.78 | Discriminant validity met |
| Structural Model | $\chi^2$/df | < 3.00 | 1.73 | Good fit |
| | CFI | ≥ 0.90 | 0.952 | Excellent fit |
| | TLI | ≥ 0.90 | 0.945 | Excellent fit |
| | RMSEA | ≤ 0.08 | 0.050 | Excellent fit |
| | SRMR | ≤ 0.08 | 0.043 | Excellent fit |
| Predictive Power ($R^2$) | DLE | — | 0.30 | Moderate |
| | 4C Skills | — | 0.57 | Substantial |
| Measurement Invariance | Configural model | ΔCFI ≤ 0.01 | 0.953 | Invariance met |
| | Metric model | ΔCFI ≤ 0.01 | 0.952 | Invariance met |
| | Scalar model | ΔCFI ≤ 0.01 | 0.951 | Invariance met |
| Alternative Model | CFI | ≥ 0.90 | 0.902 | Lower fit than hypothesized model |
| | RMSEA | ≤ 0.08 | 0.071 | Marginal fit |

### *4.3. Structural Relationships (Research Question 2)*

The second research question tested the direct and indirect structural paths among CTP, DLE, and 4C skills. The structural model demonstrated an excellent fit: $\chi^2$ (364) = 629.75, $p < .001$; $\chi^2$/df = 1.73; CFI = 0.952; TLI = 0.945; RMSEA = 0.050; SRMR = 0.043. Direct effects revealed that CTP had a significant positive effect on 4C skills ($\beta = 0.37$, $p < .001$), supporting H1. CTP also positively influenced DLE ($\beta = 0.55$, $p < .001$), supporting H2. Furthermore, DLE significantly predicted 4C skills ($\beta = 0.42$, $p < .001$), supporting H3. The model explained 30% of the variance in DLE ($R^2 = 0.30$) and 57% of the variance in 4C skills ($R^2 = 0.57$), indicating substantial predictive power according to Cohen [29] criteria.

Table 4 presents the standardized path coefficients, standard errors, critical ratios, and significance levels for all hypothesized paths. Figure 2 illustrates the final structural model with standardized coefficients.

**Table 4.**
Standardized Path Coefficients for the Structural Model.

| Path | β | SE | CR | p |
|---|---|---|---|---|
| CTP → 4C Skills | 0.37 | 0.06 | 6.17 | <0.001 |
| CTP → DLE | 0.55 | 0.05 | 10.82 | <0.001 |
| DLE → 4C Skills | 0.42 | 0.07 | 6.00 | <0.001 |

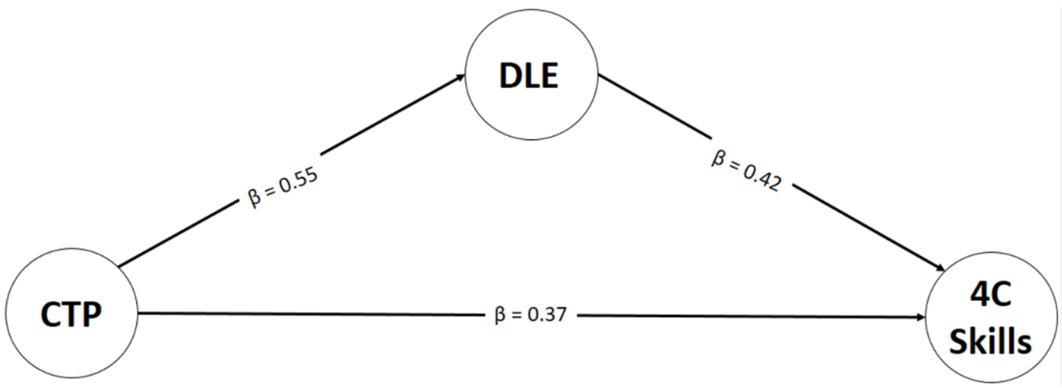


**Figure 2.**
Final structural model of the CTDL framework.

### *4.4. Mediation Analysis (Research Question 3)*

The third research question explored whether DLE mediated the relationship between CTP and 4C skills. Bootstrapping with 5,000 resamples was conducted to test the indirect effects. The indirect effect of CTP on 4C skills via

DLE was significant (β = 0.23, 95% CI [0.15, 0.32], p < .001). The direct effect remained significant in the presence of the mediator, indicating partial mediation. Table 5 presents the bootstrapped estimates for direct, indirect, and total effects.

**Table 5.**
Bootstrapped Direct, Indirect, and Total Effects

| Effect Type | Path | β | 95% CI LL | 95% CI UL | p |
|---|---|---|---|---|---|
| Direct | CTP → 4C Skills | 0.37 | 0.25 | 0.49 | <0.001 |
| Indirect | CTP → DLE → 4C Skills | 0.23 | 0.15 | 0.32 | <0.001 |
| Total | CTP → 4C Skills | 0.60 | 0.49 | 0.70 | <0.001 |

These findings indicate that while contextual teaching practices directly influence 21st-century skills, a substantial portion of their effect operates through enhancing digital learning engagement. This supports H4 and underscores the importance of fostering active, technology-mediated participation to maximize skill development in pre-service teachers.

### *4.5. Alternative Model Testing*

To strengthen the robustness of the findings, an alternative model was tested in which DLE and CTP were reversed to examine whether digital engagement might influence contextual teaching perceptions. The alternative model demonstrated a poorer fit (CFI = 0.902; RMSEA = 0.071) compared to the hypothesized model (CFI = 0.952; RMSEA = 0.050), and the reversed paths were weaker and less significant. This supports the theoretical direction of the original model and reduces concerns about model misspecification.

### *4.6. Summary of Findings*

Overall, the results confirmed that contextual teaching practices directly enhance 21st-century skills and indirectly improve them through digital learning engagement. The high level of explained variance in 4C skills (57%) suggests that the CTDL framework provides a strong predictive model for skill development in pre-service elementary teachers. The evidence of measurement invariance indicates that these relationships hold consistently across demographic subgroups, further supporting the generalizability of the model.

## 5. Discussion

The present study advances the understanding of how Contextual Teaching Practices (CTP) and Digital Learning Engagement (DLE) interplay to foster 21st-century skills (4C) among pre-service elementary teachers, as modeled through Structural Equation Modeling. Consistent with earlier constructs of Contextual Teaching and Learning, our findings reaffirm that embedding learning within real-world, authentic contexts exerts a robust direct effect on 4C competencies. Similar results were observed in Sulistiani [25] and Mazidah and Sartika [30] the present SEM-based evidence further validates this relationship with statistical rigor.

Importantly, the strong positive path from CTP to DLE echoes recent research emphasizing how pedagogical context catalyzes digital engagement. Pala and Başıbüyük [11] and Hinze, et al. [16] anticipated this connection, and our findings empirically support that context-rich pedagogy primes pre-service teachers to meaningfully embrace digital tools. From a developmental perspective, Vygotsky [18] is reinforced: technology-rich contextual scaffolding broadens learners' capacity to engage and construct new knowledge.

The significant effect of DLE on 4C outcomes also aligns with Marr [2] view of digital environments as incubators for critical thinking, collaboration, creativity, and communication. Our mediation analysis shows that DLE partially transmits the influence of CTP to 4C skills, underscoring the essential role of engaged technology use in pedagogical impact. This resonates with Marope [1], who stressed that 21st-century competencies cannot be nurtured outside the digital ecosystems that define modern learning.

Looking at the latest empirical studies adds further depth to our conclusions. A 2024 study highlighted that first-year pre-service teachers' digital self-efficacy and attitudes strongly predicted their online learning engagement—reinforcing the notion that positive dispositions are central to digital engagement [11]. Another 2023–2024 investigation revealed that early childhood pre-service teachers' positive attitudes toward technology were significantly correlated with their self-perceived digital competence, supporting the importance of affective readiness for engaging technologically to develop skills [1]. These findings mirror our results, showing that engagement is both a function of pedagogy and disposition.

A 2025 study based on the DigCompEdu framework found that half of surveyed pre-service teachers felt unprepared to foster digital competence in learners, highlighting a persistent gap in teacher education programs [25, 31]. This insight underscores the urgency of integrating structured pedagogical strategies like CTDL—combining context, technology, and engagement—to better prepare pre-service teachers. Our study responds precisely to that gap by empirically demonstrating how pedagogical design can directly and indirectly bolster both digital engagement and 21st-century skills.

Furthermore, a systematic review of professional development from 2020 to 2024 emphasized that continuous, contextually relevant training was essential to support digital instructional integration among teachers [12, 32]. Our findings extend this discourse to pre-service training, suggesting that embedding CTDL within teacher preparation may serve as foundational contextual professional development—creating a sustainable trajectory of competency development even before in-service stages.

Taken together, the present study offers several unique contributions. First, it is among the earliest to apply SEM to model the dual pathways (direct and mediated) through which contextual pedagogy and digital engagement foster 4C competencies in teacher education. This integrative mapping addresses a noted gap in empirical SEM models of teacher education—especially within digital era frameworks. Second, by juxtaposing interaction effects, structural relationships, and engagement dynamics, this study elaborates a holistic theoretical model that bridges constructivist pedagogy, socio-technological engagement, and 21st-century skill development with statistical evidence. Lastly, the partial mediation effect uncovers the nuanced role of DLE: it acts as both a mechanism and an amplifier of pedagogical influence, providing actionable insight for curriculum designers to balance context, technology, and engagement designs intentionally.

From a theoretical standpoint, this work extends the contextual teaching and learning paradigm [14, 33] into a 21st-century digital learning landscape, demonstrating that experiential, context-driven pedagogies remain highly relevant when integrated with purposeful technology use. The findings enrich Vygotskian socio-constructivist perspectives by showing that the zone of proximal development can be expanded through the strategic combination of contextual learning environments and digital engagement tools. This integration offers a nuanced view of skill development, not as a linear process, but as an interactional dynamic between pedagogy and engagement mechanisms.

Practically, the study offers clear guidance for teacher education programs. Embedding CTDL strategies into pre-service curricula can simultaneously strengthen digital competence, increase engagement with technology, and cultivate the critical, creative, collaborative, and communicative skills demanded in modern classrooms. Such integration is particularly vital given recent evidence that many pre-service teachers still feel unprepared to teach digital competence, and that affective dispositions toward technology significantly shape engagement [34, 35] By aligning instructional design with both contextual pedagogy and engagement-focused technology use, teacher educators can address these gaps more effectively.

Nonetheless, the study has limitations that future research should address. The sample was drawn from a specific cohort of pre-service elementary teachers, which may limit the generalizability of the findings to other educational contexts or disciplines. The cross-sectional design captures relationships at a single point in time; longitudinal designs could better illuminate causal pathways and developmental trajectories of skill acquisition. Additionally, while the study operationalized DLE as a mediating construct, future work could test other potential mediators or moderators, such as digital self-efficacy, teaching presence, or institutional support.

In summary, the current findings reinforce established theory, align with recent empirical studies on engagement and digital competence, and extend the conversation by modeling these interconnections quantitatively. The CTDL framework's empirical validation provides a theoretically grounded and practically relevant model for teacher educators striving to cultivate 21st-century skills within rapidly evolving digital learning environments.

## 6. Conclusion

This study set out to validate and examine the Contextual Teaching–Digital Learning (CTDL) framework as a predictor of 21st-century skills among pre-service elementary teachers using a pure quantitative SEM approach. The results revealed that contextual teaching practices (CTP) exerted a significant direct influence on 4C skills, and that digital learning engagement (DLE) both mediated and amplified this relationship. The model demonstrated strong measurement validity, structural robustness, and theoretical coherence, offering empirical confirmation of the synergistic role between contextualized pedagogy and technology-mediated engagement in fostering competencies essential for contemporary education. In conclusion, this study contributes to both theory and practice by offering a validated, empirically tested model that explains how contextual pedagogy and digital engagement converge to foster 21st-century skills. It bridges gaps in the literature, aligns with the most recent empirical findings, and provides actionable guidance for curriculum designers and teacher educators aiming to prepare educators for the demands of a digitally driven educational era. Looking ahead, future studies should explore the CTDL framework's applicability across different cultural and institutional contexts, and test its adaptability for in-service teacher professional development. Integrating mixed-methods approaches could provide richer insight into the lived experiences of learners within CTDL-based environments, complementing the statistical validation offered here. By adopting and adapting the CTDL framework, teacher education programs can more effectively prepare graduates who are not only competent in their subject matter, but also agile, adaptive, and equipped to lead learning in the dynamic classrooms of the future.

## References


[1] M. Marope, *Reconceptualizing and repositioning curriculum in the 21st century: A global paradigm shift*. Geneva, Switzerland: UNESCO International Bureau of Education, 2025.

[2] B. Marr, *Future skills: The 20 skills and competencies everyone needs to succeed in a digital world*. Hoboken, NJ: John Wiley & Sons, 2022.

[3] U. A. Pozdnyakova, V. V. Golikov, I. A. Peters, and I. A. Morozova, *Genesis of the revolutionary transition to industry 4.0 in the 21st century and overview of previous industrial revolutions. In Industry 4.0: industrial revolution of the 21st century*. Cham: Springer International Publishing, 2018.

[4] R. Rosnaeni, "Characteristics and assessment of 21st century learning," *Jurnal Basicedu,* vol. 5, no. 5, pp. 4334-4339, 2021. https://doi.org/10.31004/basicedu.v5i5.1548

[5] A. Halim, S. Farada, A. Hamid, E. Mahzum, and I. Irwandi, "Effect of concept attainment model on student's science process skills," in *Journal of Physics: Conference Series (Vol. 1882, No. 1, p. 012157). IOP Publishing*, 2021.

[6] N. Maryani and D. Widjajanti, "Mathematical literacy: How to improve it using contextual teaching and learning method?," in *Journal of Physics: Conference Series, IOP Publishing*, 2020.

[7] N. Maulidah, D. Amelia, and D. A. Maharbid, "Creative thinking habits of prospective elementary school teacher students reviewed from the cumulative achievement index," *Jurnal Elementaria Edukasia,* vol. 5, no. 1, pp. 1-13, 2022.

[8] M. Munawwarah, N. Laili, and M. Tohir, "Students' critical thinking skills in solving mathematical problems based on 21st century skills," *Alifmatika: Jurnal Pendidikan Dan Pembelajaran Matematika,* vol. 2, no. 1, pp. 37-58, 2020. https://doi.org/10.35316/alifmatika.2020.v2i1.37-58

[9] A. A. Abdullayev, "System of information and communication technologies in the education," *Science and World International Scientific Journal,* vol. 2, no. 5, pp. 19-21, 2020.

[10] H. A. Wijono, "The urgency of lecturers' psychological capital in facing the transformation of 21st-century education," *Tasyri: Jurnal Tarbiyah-Syariah-Islamiyah,* vol. 28, no. 02, pp. 172-179, 2021. https://doi.org/10.52166/tasyri.v28i02.618

[11] Ş. M. Pala and A. Başıbüyük, "The predictive effect of digital literacy, self-control and motivation on the academic achievement in the science, technology and society learning area," *Technology, Knowledge and Learning,* vol. 28, pp. 369-385, 2023. https://doi.org/10.1007/s10758-021-09538-x

[12] J. Garzon, G. Lampropoulos, and D. Burgos, "Effects of mobile learning in English language learning: A meta-analysis and research synthesis," *Electronics,* vol. 12, no. 7, p. 1595, 2023. https://doi.org/10.3390/electronics12071595

[13] E. E. M. Maryati, "Application of information discussion method in biology learning," *STRATEGY : Jurnal Inovasi Strategi dan Model Pembelajaran,* vol. 2, no. 4, pp. 474-482, 2022. https://doi.org/10.51878/strategi.v2i4.1717

[14] S. Samsudin and S. Sukarismanti, "From vocabulary building to cultural literacy: Implementing contextual teaching and learning in resource-limited EFL classrooms," *Innovations in Language Education and Literature,* vol. 2, no. 1, pp. 21-29, 2025. https://doi.org/10.31605/ilere.v2i1.5025

[15] I. A. Restu and W. Arini, "Development of physics student worksheets based on contextual teaching and learning on temperature and heat material for grade XI students of SMA Negeri 6 Lubuklinggau," *Silampari Jurnal Pendidikan Ilmu Fisika,* vol. 2, no. 2, pp. 92-106, 2020. https://doi.org/10.31540/sjpif.v2i2.985

[16] A. Hinze, N. Vanderschantz, C. Timpany, S. J. Cunningham, S.-J. Saravani, and C. Wilkinson, "A study of mobile app use for teaching and research in higher education," *Technology, Knowledge and Learning,* vol. 28, pp. 1271-1299, 2023. https://doi.org/10.1007/s10758-022-09599-6

[17] R. Zainul *et al.*, "Development of e-learning courses for subjects about 'learn and learning'with Moodle-based for prospective teacher in Indonesia," in *Journal of Physics: Conference Series, vol. 1594, no. 1, p. 012023. IOP Publishing*, 2020.

[18] L. S. Vygotsky, *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press, 1978.

[19] N. Wiener, *Cybernetics or control and communication in the animal and the machine*, 2nd ed. Cambridge, MA: MIT Press, 1985.

[20] S. Nagpal and D. Kumar, "A thematic analysis of instructional design models," *Journal of Critical Reviews,* vol. 7, no. 18, pp. 1641-1650, 2020.

[21] B. Joyce and E. Calhoun, *Models of teaching*. Abingdon, UK: Routledge, 2024.

[22] M. Asy'ari and M. Muhali, "Improving physics learning outcomes through the constructivism model with a problem-solving approach," *Lensa: Jurnal Kependidikan Fisika,* vol. 10, no. 2, pp. 54-64, 2022. https://doi.org/10.33394/j-lkf.v10i2.6870

[23] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate data analysis*, 8th ed. Andover, Hampshire, UK: Cengage Learning, 2019.

[24] R. B. Kline, *Principles and practice of structural equation modeling*, 4th ed. New York: The Guilford Press, 2016.

[25] I. R. Sulistiani, "Contextual teaching and learning (CTL) and its influence on students' mathematics learning outcomes," *ElementerIs: Jurnal Ilmiah Pendidikan Dasar Islam,* vol. 2, no. 1, pp. 40-49, 2020. https://doi.org/10.33474/elementeris.v2i1.6966

[26] J. C. Anderson and D. W. Gerbing, "Structural equation modeling in practice: A review and recommended two-step approach," *Psychological Bulletin,* vol. 103, no. 3, pp. 411–423, 1988.

[27] C. Fornell and D. F. Larcker, "Structural equation models with unobservable variables and measurement error: Algebra and statistics," *Journal of Marketing Research,* vol. 18, no. 3, pp. 382–388, 1981.

[28] L. t. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives," *Structural Equation Modeling: A Multidisciplinary Journal,* vol. 6, no. 1, pp. 1-55, 1999. https://doi.org/10.1080/10705519909540118

[29] J. Cohen, *Statistical power analysis for the behavioral sciences*, 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

[30] N. R. Mazidah and S. B. Sartika, "The influence of the contextual teaching and learning (CTL) approach on cognitive learning outcomes in science subjects for grade V at SDN Grabagan," *Jurnal Papeda: Jurnal Publikasi Pendidikan Dasar,* vol. 5, no. 1, pp. 9-16, 2023.

[31] A. Abdurahman, Y. Hayati, N. A. Manaf, and N. F. N. Azhar, "Gender roles in traditional and modern Minangkabau kaba: An analysis of ten selected narratives," *Theory and Practice in Language Studies,* vol. 14, no. 11, pp. 3504–3514, 2024. https://doi.org/10.17507/tpls.1411.19

[32] E. Waty, Y. Nengsih, C. Handrianto, M. Nurrizalia, and S. Shomedran, "Examining the psychological factors impacting teachers' constraints in creating and administering final examinations," *Journal for ReAttach Therapy and Developmental Diversities,* vol. 6, no. 7, pp. 530-540, 2023.

[33] S. Herlina, M. A. Rahman, Z. Nufus, C. Handrianto, and K. Masoh, "The development of students' learning autonomy using tilawati method at a Madrasatul Quran in South Kalimantan," *Jurnal Pendidikan Agama Islam,* vol. 18, no. 2, pp. 431-450, 2021. https://doi.org/10.14421/jpai.2021.182-12

[34] C. Handrianto *et al.*, "Validating and testing the teacher self-efficacy (TSE) scale in drug education among secondary school teachers," *International Journal of Learning, Teaching and Educational Research,* vol. 22, no. 6, pp. 45-58, 2023.

[35] N. A. Alwi, A. K. Kenedi, Y. Anita, C. Handrianto, and S. Rasool, "Socio-cultural approach through digital teaching modules: A solution to improve beginning reading skills in elementary schools," *Journal of Ecohumanism,* vol. 3, no. 7, pp. 4366–4377, 2024. https://doi.org/10.62754/joe.v3i7.4552