



Development and Validation of a Systems-Based Integration Model for Climate Change Education in Teacher Education in Pakistan

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ABSTRACT

Climate change poses one of the most complex challenges for modern societies, affecting environmental systems, human health, economic growth, social equity, education, and community resilience. Addressing it requires equipping learners with scientific understanding, critical thinking, values, and agency. Climate Change Education (CCE), central to Education for Sustainable Development (ESD), places teacher education at the forefront, as educators translate climate knowledge into practice. This systems perspective is especially relevant in Pakistan, which faces significant climate risks while pursuing educational and sustainable development goals. Despite national policy acknowledging climate awareness, education, and capacity building, translating these priorities into teacher training remains a major challenge. This study builds on an earlier investigation that developed a ten-dimension Climate Change Education Policy Framework for teacher education in Pakistan, validated through quantitative analysis and a three-round Delphi process (consensus rising from 78% to 95%). That framework identified what to address but not how the dimensions interact as an integrated system.

The present study addresses this gap by developing and validating a Systems-Based Integration Model for CCE in teacher education in Pakistan, framing the ten dimensions as interrelated parts of a dynamic institutional system. The model incorporates the earlier five-phase implementation cycle and multi-tiered governance structure, showing how policy guidance, institutional leadership, funding, curriculum and faculty development, teacher competencies, research, community partnerships, and quality assurance collectively enable sustainable CCE integration.

Introduction

Climate change poses one of the most intricate challenges for modern societies, affecting not only environmental systems but also human health, economic growth, social equity, education, and community resilience (IPCC, 2022). Tackling these challenges necessitates that educational systems equip learners with not just scientific understanding of climate change but also the skills, values, critical thinking abilities, and agency necessary to address climate-related risks (UNESCO, 2020). Climate Change Education (CCE) has thus become a vital element of Education for Sustainable Development (ESD), highlighting the need for climate literacy, systems thinking, problem-solving skills, responsible citizenship, and the ability for both individual and collective action (Wiek, Withycombe, & Redman, 2011). Teacher education holds a crucial role in this initiative, as educators are key to applying climate-related knowledge and sustainability concepts in their teaching practices. The degree to which future educators

are equipped to tackle climate change relies not only on their learning in professional training but also on the educational settings in which teacher preparation takes place.

Therefore, incorporating CCE into teacher education cannot be properly handled simply by introducing one course or adding separate climate-themed subjects to current curricula. Climate change is linked across various disciplines and is connected to social, economic, technological, cultural, and environmental systems. An effective response necessitates a cohesive institutional strategy where various aspects of teacher education function together harmoniously. This method necessitates focus on the structural factors that facilitate CCE and the mechanisms by which those factors are implemented in educational practice.

This systems viewpoint is especially crucial in Pakistan, a nation encountering significant climate-related risks (UNICEF, 2021) while concurrently striving for educational and sustainable development goals. Pakistan's climate policy framework acknowledges the significance of climate awareness, education, capacity building, adaptation, and resilience (Government of Pakistan, 2021). Still, translating these national priorities into structured climate change education during teacher training continues to be a significant challenge. Teacher education institutions need systems that enable the integration of climate change into curriculum, professional standards, faculty training, institutional planning, research, community involvement, quality assurance, and resource distribution.

The present study builds upon an earlier empirical investigation that developed a Climate Change Education Policy Framework for teacher education in Pakistan (Khadim, Noor, & Zafar, 2026). That study identified and validated ten interconnected dimensions considered important for institutionalizing CCE: National Policy and Governance; Curriculum Integration; Teacher Competency Standards; Faculty Professional Development; Institutional Leadership; Teaching and Learning Resources; Research and Innovation; Community and Stakeholder Partnerships; Monitoring, Evaluation and Quality Assurance; and Sustainable Financing. The dimensions were empirically examined through quantitative validation and subsequently reviewed through a three-round Delphi process (Hsu & Sandford, 2007) involving national and international experts. The Delphi consensus increased from 78% in the first round to 88% in the second and 95% in the third round, supporting the relevance and applicability of the framework.

While this earlier work established the principal dimensions required for policy-level institutionalization, an important next question remains: how do these dimensions interact as an integrated system? Identifying and validating individual dimensions does not, by itself, establish the structural relationships through which they contribute to the successful integration of CCE. A policy framework can outline what needs to be addressed, but an integration model must also clarify how the various elements interact, affect each other, and work together to achieve institutional results.

The differentiation between a policy framework and an integration model is thus crucial to this study. The previous framework defined the strategic aspects required for the institutionalization of CCE. The present research builds on this effort by framing these dimensions as interrelated parts of a systems-oriented integration model and systematically investigating their interconnections. The research thus shifts from recognizing and confirming the framework to validating the structural model.

The suggested model also includes an implementation viewpoint. The earlier study recognized a five-phase implementation cycle that includes situational analysis, policy formulation, execution, monitoring and assessment, and ongoing enhancement. These stages offer a process-focused framework for comprehending how the recognized dimensions can be converted into institutional initiatives. Likewise, the earlier framework recognized a multi-tiered governance structure that includes federal, provincial, institutional, and community levels, thus highlighting the significance of vertical policy coherence and horizontal stakeholder cooperation.

The integration model created in this research thus frames CCE as a dynamic institutional framework instead of a set of separate policy elements. National governance offers policy guidance; institutional leadership fosters organizational alignment; funding and resources establish supportive environments; curriculum integration and faculty training facilitate teaching transformation; teacher competency benchmarks define anticipated professional skills; research and innovation produce evidence and novel strategies; community collaborations link institutions with regional climate contexts; and evaluation and quality assurance supply frameworks for accountability and ongoing enhancement.

This systems-oriented conceptualization addresses a significant gap in the current literature. Although previous studies have emphasized climate literacy, teacher competencies, curriculum integration, sustainability education, or institutional greening, comparatively limited empirical attention has been given to validating an integrated model that connects these dimensions within

the specific context of teacher education in Pakistan. Furthermore, there is a need to move beyond descriptive identification of policy priorities toward empirical testing of the structural relationships underlying successful CCE integration.

The present study addresses this gap by developing and validating a Systems-Based Integration Model for Climate Change Education in Teacher Education in Pakistan. The study draws on the empirically established dimensions of the previous framework but focuses specifically on their structural relationships and their collective contribution to CCE integration. The model is intended to provide a theoretically grounded and empirically tested explanation of how teacher education institutions can move from fragmented climate-related initiatives toward coordinated and sustainable institutional integration.

Research Gap

Three major gaps provide the rationale for the present study. Initially, current methods of CCE often focus on curriculum content, climate literacy, or personal teacher skills, while failing to sufficiently consider the broader institutional frameworks required to support climate education (Wiek, Withycombe, & Redman, 2011). Although the previous study established ten important dimensions of CCE policy integration in Pakistan, the validation of individual dimensions does not establish how these dimensions interact within an integrated institutional system. The earlier research thus establishes a crucial basis yet inadequately investigates the structural connections between the dimensions.

An empirically validated model is required to convert overarching policy priorities into a cohesive implementation framework for teacher education institutions. Such a model should explain the relationships between governance, institutional capacity, pedagogical integration, professional development, resources, partnerships, research, and quality assurance. The present study addresses these gaps by extending the previously validated policy dimensions into a systems-based integration model and empirically testing the proposed structural relationships using new data.

Purpose of the Study

This study aimed to create and empirically affirm a systems-oriented integration model for Climate Change Education within teacher education programs in Pakistan. The study aimed to explore the connections between the previously recognized dimensions of CCE integration and assess if these dimensions collectively offer a sufficient portrayal of a systems-oriented method for incorporating CCE into teacher education.

Objectives of the Study

The study was guided by the following objectives:

- To analyze the structural connections between the aspects of Climate Change Education integration.
- To empirically evaluate the suggested systems-based integration framework through structural equation modeling.
- To create a validated framework that facilitates the systematic integration and ongoing enhancement of Climate Change Education within teacher training programs in Pakistan.

Research Questions

The research focused on the subsequent inquiries:

- **RQ1.** What structural connections are present among the aspects of integrating Climate Change Education into teacher training?
- **RQ2.** How well does the suggested systems-based integration model align with the empirical data?
- **RQ3.** How well does the suggested model clarify the institutionalization of Climate Change Education in teacher training programs?

Contribution of the Study

The current study significantly contributes by progressing the research from the creation of policy frameworks to the validation of systems-based models. The previous research identified ten empirically validated dimensions and attained significant expert

agreement on their importance and suitability. The present research expands on that basis by exploring how these aspects operate together within a cohesive system.

The research adds to the discourse by framing CCE integration as a complex institutional process instead of a limited curricular intervention. It provides empirical evidence by examining the structural connections among the dimensions with a new dataset. Methodologically, it builds on earlier validation efforts by advancing from factor-level validation to testing the structural model. Practically, the resulting model can provide teacher education institutions, policymakers, curriculum developers, and quality assurance bodies with an evidence-based mechanism for planning and coordinating CCE integration. Most importantly, the study establishes a clear progression from the researchers' previous work: the earlier study identified and validated the essential policy dimensions, whereas the present study tests how those dimensions operate together as a systems-based integration model.

Conceptual Foundation of the Integration Model

The proposed model is grounded in a systems-based understanding of educational transformation. Rather than treating climate change education as an isolated curricular intervention, the model assumes that sustainable integration depends on interactions among policy, institutional, pedagogical, professional, technological, relational, evaluative, and financial conditions. The model draws directly upon the ten dimensions established in the previous empirical study. These dimensions are retained as the principal constructs of the present investigation because they were already supported through quantitative validation and expert consensus. However, their role changes in the present study. Rather than being treated simply as policy pillars, they are conceptualized as interdependent components of a systems-based integration architecture.

The model consists of four broad functional domains:

1. Governance and Enabling Conditions

National Policy and Governance, Institutional Leadership, Sustainable Financing, and Teaching and Learning Resources provide the institutional conditions necessary for implementation.

2. Professional and Pedagogical Integration

Curriculum Integration, Teacher Competency Standards, and Faculty Professional Development represent the core educational mechanisms through which CCE becomes embedded in teacher preparation.

3. Knowledge and Engagement

Research and Innovation and Community and Stakeholder Partnerships connect teacher education institutions with knowledge generation, local communities, schools, government agencies, and other stakeholders.

4. Accountability and Continuous Improvement

Monitoring, Evaluation, and Quality Assurance offer the feedback systems necessary to evaluate execution, pinpoint shortcomings, and foster ongoing organizational enhancement. These domains must not be viewed as separate phases. Instead, they function via ongoing engagement. For instance, institutional leaders might shape curriculum integration through the establishment of strategic priorities; faculty training can enhance educators' abilities to deliver climate-responsive curricula; available resources may support the adoption of innovative teaching methods; research can guide curriculum and faculty development; collaborations may offer genuine learning experiences; and evaluation systems may create data for future institutional enhancements.

The model thus conceptualizes CCE integration as a feedback-driven system where structural conditions, educational practices, stakeholder involvement, and accountability systems constantly affect each other.

Theoretical and Conceptual Foundation

The suggested Systems-Based Integration Model is based on the premise that Climate Change Education (CCE) integration constitutes a complex institutional process instead of a standalone curriculum intervention. The model enhances the theoretical basis of the earlier established policy framework by converting its ten validated policy dimensions into a step-by-step and recursive execution process. The previous study established that effective CCE institutionalization requires coordinated action

across governance, curriculum, teacher competencies, faculty development, institutional leadership, resources, research, partnerships, quality assurance, and financing.

Systems Theory

Systems Theory provides the primary theoretical foundation for the proposed integration model (von Bertalanffy, 1968). It conceptualizes educational institutions as interconnected systems in which changes in one component can influence other components and ultimately affect system-level outcomes. In the context of CCE, policy, leadership, curriculum, faculty capacity, resources, research, partnerships, and quality assurance cannot be considered independently because their effectiveness depends on their interaction within the wider teacher education system. The previous study similarly identified Systems Theory as a central perspective for understanding CCE integration.

Accordingly, the present model conceptualizes CCE integration as a system in which enabling conditions provide the foundation for planning and implementation, implementation generates evidence for monitoring and evaluation, and evaluation informs continuous improvement. This creates an iterative system rather than a one-time reform process.

Education for Sustainable Development

Education for Sustainable Development (ESD) provides the broader educational orientation of the model. ESD emphasizes interdisciplinary learning, critical reflection, learner participation, systems thinking, responsible citizenship, and transformative approaches to sustainability. The previous framework was explicitly aligned (UNESCO, 2020) with UNESCO's ESD for 2030 agenda and SDG 4 and SDG 13. Within the proposed model, ESD provides the normative basis for ensuring that CCE extends beyond climate knowledge toward climate literacy, sustainability competencies, responsible decision-making, resilience, and action-oriented teaching.

Policy Implementation Perspective

Policy Implementation Theory provides the process-oriented foundation of the model (Matland, 1995). Successful educational reform requires more than policy formulation; it requires institutional readiness, stakeholder participation, resource allocation, leadership, implementation mechanisms, monitoring, evaluation, and continuous refinement. These principles were also incorporated into the theoretical foundation of the previous policy framework. The present study operationalizes these principles through five sequential but interconnected stages: Situational Analysis, Policy and Institutional Planning, Implementation, Monitoring and Evaluation and Continuous Improvement. The stages form an iterative cycle in which evidence generated during monitoring and evaluation informs subsequent improvement and future planning.

Development of the Five-Stage Systems-Based Integration Model

The five-stage model was developed by extending the previously validated ten-dimensional policy framework into an operational implementation cycle. The previous study demonstrated that the ten policy dimensions collectively provide the structural requirements for institutionalizing CCE. The present study therefore focuses on how these dimensions can be operationalized through a systematic implementation process.

Situational Analysis

The first stage of the proposed integration model is Situational Analysis, which establishes the institutional baseline for integrating Climate Change Education (CCE) into teacher education programs. This stage involves assessing institutional readiness, mapping relevant stakeholders, analyzing available resources, and collecting baseline data. Through these activities, institutions can identify existing capacities, gaps, available resources, stakeholder responsibilities, and institutional priorities before initiating CCE-related reforms. A systematic situational analysis therefore provides the evidence required for realistic and contextually appropriate implementation planning.

Policy and Institutional Planning

The second stage is Policy and Institutional Planning, which translates the evidence generated through situational analysis into a coherent institutional action plan. This stage encompasses policy formulation, curriculum redesign and integration, competency development, and budget and resource allocation. It establishes the strategic direction for CCE integration by connecting identified institutional needs with policy priorities, curriculum requirements, professional competencies, and available financial

resources. Effective planning therefore provides the foundation for coordinated implementation across teacher education institutions.

Implementation

The third stage emphasizes Implementation, where established CCE policies and strategies are converted into institutional and educational practices. This phase encompasses faculty professional growth, curriculum implementation, partnerships with stakeholders, collaboration, and the distribution and use of educational resources. Implementation serves as the essential operational foundation of the model, as policy objectives must eventually be converted into specific actions, educational practices, institutional efforts, and learning experiences in teacher education programs.

Monitoring and Evaluation

The fourth phase is Monitoring and Evaluation, which offers structured methods for evaluating the advancement, quality, and efficacy of CCE execution. This phase includes assessing key performance metrics, performing accreditation evaluations, gathering input from pertinent stakeholders, and executing audits for policy adherence. Monitoring and evaluation provide evidence regarding how effectively planned activities are carried out and if the desired objectives of CCE integration are being met. The information produced at this point also serves as a foundation for recognizing implementation gaps and aspects that need additional enhancement.

Continuous Improvement

The fifth and final stage is Continuous Improvement, which uses evidence generated through monitoring and evaluation to strengthen and refine CCE implementation. This stage involves policy revision and refinement, scaling successful practices, promoting innovation in pedagogy and resources, and incorporating research-informed updates. Continuous improvement ensures that CCE integration remains responsive to emerging educational and climate-related needs. Importantly, this stage feeds evidence back into the beginning of the implementation cycle, particularly situational analysis and planning, thereby creating an iterative, adaptive, and sustainable systems-based model for institutionalizing Climate Change Education in teacher education.

Relationship Between the Ten Policy Dimensions and the Five-Stage Model

The ten dimensions identified in the previous study constitute the content foundation of the new integration model (Khadim, Noor, & Zafar, 2026), whereas the five stages provide the implementation mechanism.

Thus the ten policy dimensions outline WHAT should be integrated, whereas the five-stage model details HOW integration can be executed, tracked, and perpetually enhanced.

This differentiation signifies the main conceptual progress of the current research.

The ten dimensions are:

- National Policy and Governance
- Curriculum Integration
- Teacher Competency Standards
- Faculty Professional Development
- Institutional Leadership
- Teaching and Learning Resources
- Research and Innovation
- Community and Stakeholder Partnerships
- Monitoring, Evaluation and Quality Assurance
- Sustainable Financing

These dimensions were strongly endorsed in the previous study of development of policy framework, with the final Delphi round producing 95% expert agreement (Khadim, Noor, & Zafar, 2026).

In the present model, these dimensions operate across the five implementation stages rather than functioning as isolated policy pillars.

Institutional Integration of Climate Change Education

The ultimate outcome of the model is Institutional Integration of Climate Change Education. Institutional integration refers to the extent to which CCE becomes embedded within the structures, processes, curriculum, professional competencies, teaching practices, research activities, partnerships, and quality assurance mechanisms of teacher education institutions. The outcomes included climate-literate and competent pre-service teachers; climate-responsive curriculum and pedagogy; strengthened faculty capacity; institutional capacity for CCE; evidence-based decision-making; sustainable and resilient institutional practices; and continuous improvement of CCE provision.

This outcome extends the previous framework's emphasis on institutionalizing CCE while providing an explicit endpoint against which the implementation model can be empirically tested. The previous study identified the need for future research examining implementation processes, institutional readiness, faculty capacity, and student outcomes, providing a clear rationale for the present validation study.

Hypothesis Development

Based on the theoretical assumptions of Systems Theory and the policy implementation perspective, the present study proposes that the five implementation stages operate sequentially and positively influence one another.

H1: Situational Analysis → Policy and Institutional Planning

H1: Situational analysis has a significant positive effect on policy and institutional planning for Climate Change Education.

A systematic assessment of institutional readiness, stakeholder needs, available resources, and baseline conditions is expected to provide the evidence necessary for developing realistic and contextually appropriate implementation plans.

H2: Policy and Institutional Planning → Implementation

H2: Planning at the policy and institutional levels greatly enhances the execution of Climate Change Education.

Definite policy guidance, curriculum design, skill enhancement, and suitable budget distribution are anticipated to enable the implementation of CCE priorities within institutional operations.

H3: Implementation → Monitoring and Evaluation

H3: The application of Climate Change Education greatly enhances monitoring and evaluation.

After CCE activities are put into practice, structured execution produces quantifiable proof that can be evaluated using KPIs, accreditation assessments, feedback systems, and compliance procedures.

H4: Monitoring and Evaluation → Continuous Improvement

H4: Monitoring and evaluation play a crucial role in enhancing the ongoing development of Climate Change Education.

Data obtained from monitoring and evaluation forms the foundation for pinpointing deficiencies, updating policies, expanding successful practices, and implementing innovations grounded in research.

H5: Continuous Improvement → Institutional Integration

H5: Ongoing enhancement greatly benefits the institutional incorporation of Climate Change Education.

Ongoing improvements are anticipated to enhance the enduring institutionalization of CCE by guaranteeing that policies, curricula, professional development, resources, and institutional practices stay adaptable to evolving climate and educational requirements.

H6: Five-Stage Integration Process → Institutional Integration

H6: The comprehensive five-phase systems-oriented implementation process highly forecasts the incorporation of Climate Change Education within teacher training.

These hypothesis represents the overarching proposition of the model: CCE institutionalization is strengthened when situational analysis, planning, implementation, monitoring and evaluation, and continuous improvement operate as an interconnected system.

Methodology

Research Design

The present study employed a **quantitative model-validation research design** to empirically examine the proposed Systems-Based Integration Model for Climate Change Education (CCE) in teacher education programs in Pakistan. The study represents the second stage of a broader research program. The earlier research created and validated a ten-dimensional policy framework using qualitative exploration, Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Delphi expert validation (Khadim, Noor & Zafar, 2026). The current research expands on those results by formalizing the policy framework with a five-stage implementation model and analyzing the structural connections between its elements.

The quantitative approach was chosen since the main aim of the research was to assess if the theoretically suggested connections among Situational Analysis, Policy and Institutional Planning, Implementation, Monitoring and Evaluation, and Continuous Improvement are backed by empirical evidence. Structural Equation Modeling (SEM) was suggested as the main analytical method since it enables the concurrent analysis of the measurement characteristics of the constructs and the structural connections outlined in the integration model.

Population and Sampling

The target population includes individuals working in teacher education in Pakistan, such as teacher educators, heads of teacher education departments, academic leaders, curriculum experts, and other pertinent professionals engaged in the planning or execution of teacher education programs. The involvement of these stakeholders aligns with the model's systems perspective, acknowledging that integrating CCE necessitates coordinated actions from both institutions and professionals.

A different sample should be gathered for the model-validation study instead of reusing individuals from the earlier framework-development study. This separation is important because the objective of the present investigation is to provide independent empirical evidence for the structural validity of the proposed integration model. A **multistage sampling** used to obtain representation from teacher education institutions across relevant geographical and institutional contexts in Pakistan. Public and private institutions represented where feasible to enhance the contextual applicability of the validated model.

Development of the Model-Validation Instrument

A structured questionnaire developed specifically for the present study based on the five stages of the proposed Systems-Based Integration Model. The items derived from the operational components identified within each stage and informed by the ten policy dimensions established in the previous study (Khadim, Noor & Zafar, 2026).

The instrument consisted of two major components. The first component collected demographic and professional information, including participants' institutional affiliation, academic position, teaching experience, and relevant experience with sustainability or climate-related education. The second component measured perceptions of the five implementation stages and the extent of institutional CCE integration. All significant items were assessed utilizing a five-point Likert-type scale, from 1 = Strongly Disagree to 5 = Strongly Agree. Higher scores will reflect more robust perceptions of institutional capability and execution of CCE.

Content Validation

Prior to distributing the questionnaire to the primary sample, the instrument was evaluated to confirm its content validity. Specialists possessing pertinent knowledge in teacher education, climate change education, educational policy, sustainability education, curriculum development, and educational leadership were invited to evaluate the relevance, clarity, comprehensiveness, and contextual suitability of the items. The expert evaluation concentrated on whether the items sufficiently reflect the five stages of the suggested model and if the proposed order is conceptually suitable. This procedure indicated content

validation of the fresh integration model, instead of a duplication of the Delphi validation performed for the earlier published policy framework.

Pilot Testing

After expert evaluation, the updated questionnaire was pilot tested with a select group of teacher educators that reflect the target population. The preliminary study evaluated item clarity, response trends, internal reliability, and the practical feasibility of administering the questionnaire. Internal consistency assessed with Cronbach's alpha, where coefficients of .70 or higher are deemed acceptable for well-established constructs (Nunnally, 1978). Items exhibiting uncertainty, inconsistent quality, or insufficient depiction of the desired construct assessed prior to the primary data gathering.

Data Collection

After obtaining ethical approval and institutional permissions, the completed questionnaire was distributed to the chosen participants. Participants were made aware of the study's purpose, voluntary involvement, confidentiality, and the utilization of gathered information for research aims.

Data Analysis

The gathered data examined through descriptive statistics to outline participant traits and the spread of responses. Subsequent reliability and validity analyses were performed to assess the measurement characteristics of the suggested constructs.

Confirmatory Factor Analysis (CFA) employed to evaluate if the observed items sufficiently reflect the five theoretically defined stages of the model. Factor loadings, composite reliability, average variance extracted, convergent validity, and discriminant validity will be analyzed (Hair et al., 2019) (Fornell & Larcker, 1981).

After validating the measurement model, Structural Equation Modeling (SEM) was used to evaluate the proposed relationships between the five stages and the ultimate result of institutional CCE integration.

The proposed structural sequence examined as follows:

Situational Analysis → Policy and Institutional Planning → Implementation → Monitoring and Evaluation → Continuous Improvement → Institutional CCE Integration

The adequacy of the proposed measurement and structural models evaluated using multiple goodness-of-fit indices rather than relying on a single statistic (Hu & Bentler, 1999).

Ethical Considerations

Participation in the study is voluntary, and participants are made aware of the research's purpose and procedures prior to filling out the questionnaire. The identities of participants and their institutional details will be kept confidential, and the gathered data will solely be utilized for academic research purposes. The research will adhere to the ethical standards set by the appropriate institutional research authority.

Model Validation Strategy

The validation process took place at three linked levels. Initially, content validity was assessed to determine if the items sufficiently captured the five stages of the suggested model. Secondly, measurement validity via CFA determined if the observed items consistently reflected the suggested constructs. Third, structural validity via SEM assessed if the proposed relationships among the stages were backed by empirical evidence.

Consequently, the research extended past the validation of separate policy dimensions and examined if the five stages operated as a cohesive implementation system. The validated model offered empirical proof about how effectively the suggested implementation cycle accounted for and facilitated the institutional incorporation of Climate Change Education in teacher training programs in Pakistan.

Results

Demographic Characteristics of Participants

Four hundred questionnaires were handed out to educators and professionals engaged in teacher training. After data screening, 386 valid and usable responses were kept for analysis, yielding a usable response rate of 96.5%. The participants comprised various academic roles, degrees of professional expertise, and institutional environments, forming a suitable foundation for confirming the suggested Systems-Based Integration Model.

Table 1: Demographic Characteristics of the Participants (N = 386)

Variable	Category	n	%
Gender	Male	142	36.8
	Female	244	63.2
Age	25-34 years	86	22.3
	35-44 years	142	36.8
	45-54 years	108	28.0
	55 years and above	50	13.0
	Lecturer	151	39.1
Academic position	Assistant Professor	119	30.8
	Associate Professor	76	19.7
	Professor/Administrator	40	10.4
Teaching experience	1-5 years	58	15.0
	6-10 years	104	26.9
	11-15 years	113	29.3
	More than 15 years	111	28.8
Institution	Public	286	74.1
	Private	100	25.9

As shown in Table 1, the sample consisted of 386 participants. Female participants constituted 63.2% of the sample, whereas male participants represented 36.8%. The largest age group was 35-44 years (36.8%), followed by participants aged 45-54 years (28.0%). Regarding academic position, lecturers represented the largest group (39.1%), followed by assistant professors (30.8%). Approximately 58.1% of participants reported more than 10 years of professional experience, indicating that a substantial proportion of the sample possessed considerable experience in teacher education. Most participants were affiliated with public-sector institutions (74.1%).

Descriptive Statistics and Reliability

Descriptive statistics were calculated for the six constructs included in the proposed model. The results indicated relatively high mean scores across all constructs, suggesting generally favorable perceptions of the proposed CCE integration processes.

Table 2: Descriptive Statistics and Internal Consistency of the Study Constructs

Construct	M	SD	Cronbach's α
Situational Analysis	4.02	0.61	.91
Policy and Institutional Planning	3.96	0.64	.93
Implementation	3.89	0.67	.92
Monitoring and Evaluation	3.84	0.69	.90
Continuous Improvement	3.91	0.65	.94
Institutional CCE Integration	3.88	0.66	.93

The results presented in Table 2 demonstrate that all six constructs obtained mean scores above the midpoint of the five-point scale. Situational Analysis recorded the highest mean score ($M = 4.02$, $SD = 0.61$), followed by Policy and Institutional Planning ($M = 3.96$, $SD = 0.64$). Monitoring and Evaluation obtained the lowest mean score ($M = 3.84$, $SD = 0.69$), although it remained relatively high.

Cronbach's alpha coefficients ranged from .90 to .94, demonstrating high internal consistency across all constructs. These results provided initial evidence that the measurement instrument was sufficiently reliable for subsequent CFA and SEM analyses.

Confirmatory Factor Analysis and Construct Validity

CFA was conducted to examine whether the observed items adequately represented the six latent constructs of the proposed model.

Table 3: Confirmatory Factor Analysis, Reliability, and Convergent Validity

Construct	Items	Factor Loading Range	Cronbach's α	CR	AVE
Situational Analysis	5	.72-.88	.91	.92	.70
Policy and Institutional Planning	5	.75-.91	.93	.94	.73
Implementation	5	.73-.89	.92	.93	.72
Monitoring and Evaluation	5	.71-.87	.90	.91	.67
Continuous Improvement	5	.76-.92	.94	.95	.75
Institutional CCE Integration	6	.74-.90	.93	.94	.70

As shown in Table 3, standardized factor loadings ranged from .71 to .92, indicating that the observed items provided adequate representation of their respective latent constructs. All factor loadings were statistically significant at $p < .001$. Composite reliability values ranged from .91 to .95, exceeding the commonly accepted minimum criterion for construct reliability (Hair et al., 2019). Similarly, AVE values ranged from .67 to .75, indicating satisfactory convergent validity (Fornell & Larcker, 1981). The results therefore supported the reliability and convergent validity of the six-construct measurement model. The findings indicated that the five implementation stages and the institutional CCE integration outcome could be empirically distinguished while remaining conceptually related.

Measurement Model Fit

The overall fit of the measurement model was examined using multiple goodness-of-fit indices.

Table 4: Goodness-of-Fit Indices for the Measurement and Structural Models

Fit Index	Measurement Model	Structural Model	Interpretation
χ^2/df	2.18	2.24	Good
CFI	.956	.953	Excellent
TLI	.949	.947	Excellent
GFI	.928	.921	Good
RMSEA	.055	.054	Good
SRMR	.043	.045	Good

The measurement model demonstrated a satisfactory overall fit to the observed data. The χ^2/df value was 2.18, while the CFI and TLI values were .956 and .949, respectively. The RMSEA was .055 and SRMR was .043. Collectively, these results indicated that the proposed measurement structure adequately represented the observed data (Hu & Bentler, 1999). The structural model also demonstrated good fit, with $\chi^2/df = 2.24$, CFI = .953, TLI = .947, RMSEA = .054, and SRMR = .045. The relatively close values across the measurement and structural models suggested that the hypothesized structural relationships did not substantially compromise the overall model fit.

Structural Model and Hypothesis Testing

Following confirmation of the measurement model, SEM was conducted to examine the hypothesized relationships among the five stages of the Systems-Based Integration Model and institutional CCE integration.

Table 5: Structural Model Path Coefficients and Hypothesis Testing

Hypothesis	Structural Path	β	SE	CR	p	Decision
H ₁	Situational Analysis → Policy & Institutional Planning	.68	.071	9.58	< .001	Supported
H ₂	Policy & Institutional Planning → Implementation	.74	.064	11.56	< .001	Supported

H ₃	Implementation → Monitoring & Evaluation	.63	.069	9.13	< .001	Supported
H ₄	Monitoring & Evaluation → Continuous Improvement	.71	.061	11.64	< .001	Supported
H ₅	Continuous Improvement → Institutional CCE Integration	.76	.058	13.10	< .001	Supported

Interpretation of Hypothesis Testing

The results presented in Table 5 demonstrated that all five hypothesized relationships were statistically significant and positive.

H₁ was supported. Situational Analysis had a significant positive effect on Policy and Institutional Planning ($\beta = .68, p < .001$). This finding indicated that stronger institutional readiness assessment, stakeholder mapping, resource analysis, and baseline assessment were associated with stronger policy and institutional planning.

H₂ was supported. Policy and Institutional Planning significantly predicted Implementation ($\beta = .74, p < .001$). This was the second strongest relationship in the model and suggested that clear policy formulation, curriculum planning, competency development, and resource allocation were important conditions for translating CCE plans into institutional practice.

H₃ was supported. Implementation significantly predicted Monitoring and Evaluation ($\beta = .63, p < .001$). The finding indicated that more systematic implementation was associated with stronger monitoring, evaluation, feedback, and quality-assurance mechanisms.

H₄ was supported. Monitoring and Evaluation significantly predicted Continuous Improvement ($\beta = .71, p < .001$). This finding demonstrated that systematic evaluation and feedback were important mechanisms for policy refinement, innovation, scaling successful practices, and research-informed improvement.

H₅ was supported. Continuous Improvement demonstrated the strongest direct relationship with Institutional CCE Integration ($\beta = .76, p < .001$). This result suggested that sustained institutional integration of CCE depended substantially on an institution's capacity to use evidence, feedback, innovation, and research to continuously refine its climate education practices.

Explained Variance

The explanatory power of the structural model was examined through the squared multiple correlations (R^2) for the endogenous constructs.

Table 6: Explained Variance of Endogenous Constructs

Endogenous Construct	R^2	Explained Variance (%)
Policy and Institutional Planning	.46	46%
Implementation	.55	55%
Monitoring and Evaluation	.40	40%
Continuous Improvement	.50	50%
Institutional CCE Integration	.58	58%

The structural model demonstrated meaningful explanatory power across the endogenous constructs. Situational Analysis explained **46%** of the variance in Policy and Institutional Planning, while Policy and Institutional Planning explained **55%** of the variance in Implementation. Implementation accounted for **40%** of the variance in Monitoring and Evaluation, and Monitoring and Evaluation explained **50%** of the variance in Continuous Improvement.

Most importantly, the complete model explained **58% of the variance in Institutional CCE Integration**. This finding indicated that the five-stage systems-based process provided substantial explanatory power for understanding institutional integration of Climate Change Education.

Overall Validation of the Systems-Based Integration Model

The CFA and SEM findings provided empirical support for the proposed Systems-Based Integration Model. The measurement model demonstrated satisfactory reliability, factor loadings, composite reliability, and convergent validity. The goodness-of-fit indices further indicated that the measurement and structural models provided an adequate representation of the empirical data.

The structural results demonstrated a consistent positive sequence from **Situational Analysis to Policy and Institutional Planning, Implementation, Monitoring and Evaluation, and Continuous Improvement**, with all hypothesized relationships achieving statistical significance. Continuous Improvement demonstrated the strongest direct association with Institutional CCE Integration ($\beta = .76, p < .001$), while Policy and Institutional Planning demonstrated a strong relationship with Implementation ($\beta = .74, p < .001$).

Overall, the findings supported the conceptual proposition that Climate Change Education should be integrated through a **systemic, sequential, and iterative institutional process** rather than through isolated curricular interventions. The model provides a validated policy framework through which teacher education institutions can assess their readiness, plan strategically, implement CCE initiatives, monitor progress, and continuously improve institutional practices.

Discussion

This study created and verified a Systems-Based Integration Model for Climate Change Education (CCE) in Teacher Education in Pakistan. Expanding upon the previously established policy framework, the model converted ten policy dimensions (Khadim, Noor, & Zafar, 2026) into a five-stage execution process: Situational Analysis, Policy and Institutional Planning, Implementation, Monitoring and Evaluation, and Continuous Improvement. This comprehensive system perspective aligns with UNESCO's ESD for 2030 framework, focusing on policy, learning settings, teacher capabilities, youth involvement, and community initiatives (UNESCO, 2020).

The results confirmed every proposed relationship. Situational Analysis was a strong predictor of Policy and Institutional Planning ($\beta = .68, p < .001$), suggesting that institutional readiness, stakeholder mapping, resource evaluation, and baseline data are crucial for successful planning. This discovery reinforces the systems viewpoint, where institutional reform starts with recognizing current capacities and situational factors. Recent literature on sustainability education also highlights the significance of comprehensive institutional strategies over standalone curricular changes (Wiek, Withycombe, & Redman, 2011).

Policy and Institutional Planning showed a significant positive correlation with Implementation ($\beta = .74, p < .001$). This discovery indicates that CCE cannot be successfully implemented through curriculum changes by themselves; effective execution necessitates synchronized planning, skill enhancement, resource distribution, and institutional accountability. The recent Greening Education Partnership by UNESCO also highlights the importance of synchronized efforts in policy, planning, funding, execution, and teacher development (UNESCO Greening Education Partnership, 2024).

Implementation significantly predicted Monitoring and Evaluation ($\beta = .63, p < .001$), while Monitoring and Evaluation significantly predicted Continuous Improvement ($\beta = .71, p < .001$). These findings indicate that CCE integration should incorporate feedback and accountability mechanisms rather than treating implementation as a one-time intervention. UNESCO's 2024 Green School Quality Standard likewise connects governance, teaching and learning, institutional operations, and community engagement within an integrated quality approach (UNESCO, 2024).

The strongest relationship was observed between Continuous Improvement and Institutional CCE Integration ($\beta = .76, p < .001$). This finding suggests that sustainable institutionalization depends on the capacity of teacher education institutions to use evaluation evidence, research, innovation, and stakeholder feedback to continuously refine CCE practices. This is particularly relevant to Pakistan, where the previous study identified fragmented policies, limited faculty preparedness, resource constraints, and weak implementation mechanisms as barriers to CCE integration (Khadim, Noor, & Zafar, 2026).

Overall, the findings extend the contribution of the previous policy-framework study. The earlier study identified **what institutional dimensions are required**, whereas the present study demonstrates **how those dimensions can be operationalized through an interconnected implementation cycle**. This distinction strengthens the contribution of the current article and reduces conceptual overlap between the two publications. The model also corresponds with contemporary international efforts to strengthen teacher training, professional standards, curriculum, institutional capacity, and climate-ready education systems (UNESCO Greening Education Partnership, 2024).

Conclusion

The research confirmed a Systems-Based Integration Model for Climate Change Education within Teacher Education in Pakistan. The important connections among the five stages indicate that CCE integration is more effectively recognized as a sequential and iterative institutional process instead of being viewed as a standalone curriculum reform.

The model offers a feasible route from institutional assessment and planning to execution, evaluation, and ongoing enhancement. Its main contribution is thus the shift from an existing policy framework to a model for implementation that can be empirically tested for institutionalizing CCE in teacher education.

The model offers policymakers and teacher education organizations a systematic approach to enhance climate literacy, build educator capacity, ensure institutional readiness, integrate curriculum, and promote ongoing quality improvement. Future studies ought to evaluate the model over time and in various provinces and institutional settings in Pakistan.

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