Environmental Knowledge Sharing: Scale Development and Validation in the Context of Organizational Green Transformation

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Abstract

Organizations need employees to exchange and transform environmental knowledge if green policies are to become routine practices, yet existing knowledge-sharing measures do not fully capture the environmental, institutional, and practice-oriented attributes of this process. This study develops and initially validates an environmental knowledge-sharing scale for organizational green transformation. Conceptually, the scale distinguishes environmental knowledge contribution, environmental knowledge acquisition, and environmental knowledge integration, with integration defined as the combination and internalization of exchanged environmental knowledge rather than downstream organizational performance. Following a multistage scale-development procedure, twelve candidate items were generated from prior research and green-management practice, assessed by five experts, and pretested with eighty employees. An online formal survey yielded 618 valid employee responses from registered construction enterprises in Hainan Province, China. The cleaned data were divided into two non-overlapping subsamples: 302 respondents for exploratory factor analysis and 316 different respondents for confirmatory factor analysis. Principal-axis factoring with Promax rotation and parallel analysis supported three factors and identified two psychometrically ambiguous items for sequential removal, resulting in a ten-item scale. Confirmatory factor analysis in the non-overlapping validation subsample indicated satisfactory fit: chi-square with 32 degrees of freedom was 36.672, the probability value was 0.261, the comparative fit index was 0.999, the Tucker–Lewis index was 0.998, the root mean square error of approximation was 0.015, and the standardized root mean square residual was 0.019. Standardized loadings ranged from 0.765 to 0.885, reliability coefficients ranged from 0.854 to 0.893, average variance extracted ranged from 0.650 to 0.735, and all heterotrait–monotrait ratios were below 0.423. Alternative measurement models fitted substantially worse. The scale provides a concise instrument for studying employee-level environmental knowledge processes, while cross-context, multi-source, predictive, and measurement-invariance validation remain necessary.

Keywords: Environmental Knowledge Sharing, Scale Development, Green Transformation, Knowledge Management, Sustainable Performance

1. Introduction

Global climate governance, carbon neutrality commitments, and sustainable development goals are reshaping the logic of corporate competition. Corporate green transformation is no longer just a matter of regulatory compliance, but a comprehensive proposition of strategic resilience, organizational reputation, resource efficiency, and long-term viability. For industries with high resource consumption, complex project collaboration, and sensitive environmental responsibilities, green transformation is not a single project, but a restructuring of organizational capabilities across departments, positions, and processes. Technology can be purchased, systems can be formulated, and equipment can be updated. The real key to whether green transformation can be implemented lies in whether environmental knowledge can move from a few departments to full sharing, from fragmented experience to organizational capability, and from paper standards to practical action. The knowledge-based view holds that knowledge is the core strategic resource of an enterprise, and an organization's competitive advantage stems from its ability to acquire, integrate, and apply knowledge [1]. In the context of green transformation, environmental knowledge includes not only energy-saving and emission-reduction technologies, environmental management standards, green construction processes, and pollution prevention methods, but also employees' shared understanding of green values, environmental responsibility, and sustainable practices. Environmental knowledge is clearly contextually embedded and action-oriented; only when continuously shared, absorbed, and integrated within organizations can it be transformed into green innovation

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capabilities and sustainable performance outcomes. Management practices such as green leadership, green human resource management, and green organizational culture can enhance employees' green awareness and organizational sustainability performance [2], [3]. Existing research lacks a context-sensitive and independently validated measure of environmental knowledge sharing. Generic scales focus primarily on exchanging work experience, technical information, and business knowledge [4], [5], [6], typically distinguishing only knowledge contribution and acquisition. Existing environmental measures also rely on a limited number of global items and rarely distinguish the integration of exchanged knowledge. Their limited use of systematic construct development and non-overlapping samples for exploratory and confirmatory validation further constrains conceptual clarity, structural stability, and cross-study comparability.

In green transformation, environmental knowledge sharing involves more than providing and acquiring information. Knowledge from different sources must also be compared, integrated, transformed, and embedded in workflows, team standards, and green improvement plans. Without integration, exchanged environmental knowledge may not translate into green practices or sustainable performance. This study therefore conceptualizes environmental knowledge sharing as comprising environmental knowledge contribution, acquisition, and integration. Accordingly, the study develops and initially validates a context-specific Environmental Knowledge Sharing Scale. Twelve candidate items were evaluated using 618 valid responses randomly divided into non-overlapping subsamples for exploratory factor analysis ($n = 302$) and confirmatory factor analysis ($n = 316$). The resulting 10-item scale is intended for employees of construction enterprises undergoing green transformation. Cross-country, multi-source, and predictive validity remain priorities for subsequent validation.

2. Literature Review

2.1. Theoretical Foundations of Environmental Knowledge Sharing

The knowledge-based view offers a resource-and-capability lens on environmental knowledge sharing, positing knowledge as a strategic resource whose value depends not merely on its stock but on the processes of acquisition, sharing, integration, and application [1]. Del Giudice and Cillo [7] note that organizational knowledge creation is a continuous transformation between explicit and tacit knowledge across individuals, teams, and organizations; knowledge yields capability only when it flows, and value only when it is integrated. While the knowledge-based view explains why environmental knowledge sharing matters, social exchange theory explains why it occurs. Sharing is not automatic: employees' willingness to contribute environmental knowledge and integrate green information depends on trust, reciprocity, relationship quality, organizational support, and psychological safety. Social exchange theory holds that such behavior is embedded in organizational exchange relationships, such that perceived recognition or reciprocation encourages continued participation [8], with reciprocity norms, organizational climate, and individual attitudes further shaping this willingness [9]. Given that sharing environmental experience or promoting knowledge integration may demand extra effort and challenge existing routines, environmental knowledge sharing constitutes both knowledge behavior and social behavior. Accordingly, this study conceptualizes environmental knowledge sharing through dual logic: it is the mechanism through which organizations convert environmental knowledge into green capability (knowledge-based view), and it depends on employees' reciprocal engagement within organizational relationships (social exchange theory). Together, these perspectives justify treating environmental knowledge sharing as a distinct construct within the green transition context.

2.2. Construct Definition and Dimensional Structure

Drawing on the knowledge-based view, social exchange theory, and knowledge-sharing research, this study conceptualizes environmental knowledge sharing as comprising environmental knowledge contribution, acquisition, and integration. Knowledge-sharing studies commonly view contribution and acquisition as the core processes through which individuals provide and obtain knowledge [10], [11], [12]. Green knowledge management research also identifies the acquisition, sharing, and application of green knowledge as essential for converting environmental information into organizational capabilities [13]. In green transformation, however, knowledge must also be interpreted, integrated, and embedded in work processes. Because competitive advantage depends not only on possessing knowledge but also on integrating and applying it [14], environmental knowledge integration is included to capture the transformation of individual environmental knowledge into organizational capability.

Environmental knowledge contribution is the output dimension, referring to employees' proactive sharing of environmental experiences, information, suggestions, and practices with colleagues, teams, or the organization. It converts personal knowledge into a shared organizational resource and supports knowledge diffusion and collective learning [15], [16]. This process is particularly relevant because frontline employees often possess practical knowledge of energy conservation, emission reduction, pollution control, and process improvement.

Environmental knowledge acquisition is the input dimension, referring to employees' active efforts to seek, collect, learn, and absorb environmental knowledge from others. Knowledge sharing involves both providing knowledge and actively seeking, receiving, and absorbing it [17]. As environmental standards, green technologies, and low-carbon practices continue to evolve, acquisition enables employees to update their environmental knowledge, identify green issues, and develop appropriate solutions.

Environmental knowledge integration refers to combining, interpreting, and reconciling environmental knowledge from different individuals and organizational sources into a coherent, work-relevant understanding. This definition follows the knowledge-based view, which regards the integration of specialized individual knowledge as a fundamental organizational mechanism [1], and related research defining integration as the synthesis of specialized knowledge into situation-specific collective knowledge [32]. In the environmental context, this process enables knowledge acquired through organizational learning and other sources to support subsequent green activities and innovation [18].

Knowledge integration and knowledge application are related but conceptually distinct. Previous studies treat knowledge acquisition, integration, and application as separate knowledge-management processes [33], while also identifying integration as a component or precursor of effective application [32]. Accordingly, environmental knowledge integration is defined here as the combination, interpretation, internalization, and translation of exchanged knowledge into a work-relevant understanding, rather than by subsequent outcomes such as green innovation or sustainable performance. Within this definition, EKS10, "I apply the green knowledge I have acquired to my work," captures the immediate internalization and work-level enactment of acquired knowledge. EKS12, "I translate external green information into internal process practices," reflects the translation of external knowledge into an internally meaningful form. Both indicators represent the proximal transformation of environmental knowledge, whereas green innovation, organizational capability, and sustainable performance remain downstream outcomes [18]. Because the survey does not include a separate measure of knowledge application or utilization, future validation research should directly examine the empirical distinctiveness of these related constructs. Their conceptual distinctions are summarized in table 1.

Table 1. Construct Definitions and Theoretical Sources

Definitions	References
Environmental knowledge contribution refers to employees' proactive provision of environmental experiences, information, suggestions, and practices to colleagues, teams, or the organization, thereby converting individual environmental knowledge into shared organizational resources.	Bock, et al. [18]; Yu, et al. [13]; Van den Hooff and Ridder [19]
Environmental knowledge acquisition refers to employees' active efforts to seek, learn, collect, and absorb environmental-management knowledge from colleagues, organizational sources, and external sources in order to update their green knowledge and improve problem-solving capability.	Van den Hooff and Ridder [19]; Wang and Noe [20]; Yu, et al. [13]
Environmental knowledge integration refers to the process through which environmental knowledge obtained from different individuals and organizational sources is combined, interpreted, reconciled, and translated into a coherent work-relevant understanding that can support subsequent knowledge application. In this study, integration is treated as related to, but not equivalent to, downstream knowledge application and its organizational outcomes.	Grant [1]; Cui et al. [18]; Alavi and Tiwana [32]; Dahiyat [33]

3. Methodology

This study followed established scale-development procedures [21], [22]. The research proceeded through construct definition, item generation, expert evaluation, pretest, main survey, and sample split. The first group analyzes using exploratory factor analysis, item purification results in final item set. The second group analyzes using confirmatory factor analysis, reliability and validity assessment, and then perform alternative-model comparison to ensure the best fitting of the final scale, as shown in figure 1.

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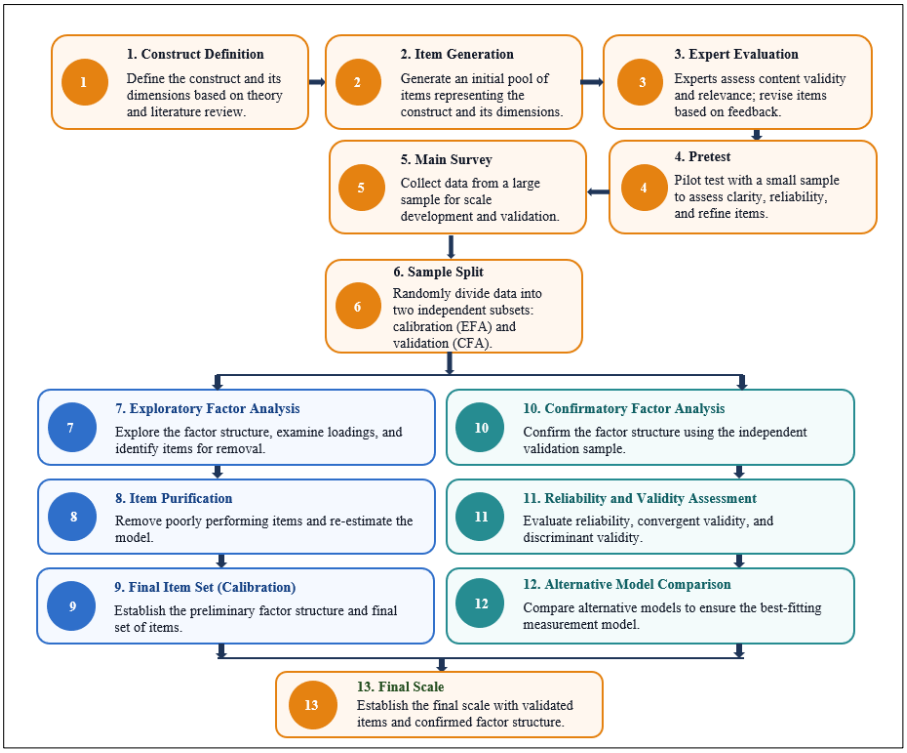


Figure 1. Scale Development and Validation Procedure.

3.1. Initial Item Generation

The initial items were primarily derived from three aspects. First, referencing classic knowledge sharing research on the measurement of knowledge contribution and acquisition [18], [19], [20], core behavioral content related to knowledge provision, knowledge seeking, and knowledge absorption was extracted. Second, refer to the Green Knowledge Management Scale and Related Research [13], embed general knowledge sharing statements into specific contexts such as environmental management, energy conservation and emission reduction, green standards, and sustainable practices, so that the questions reflect the content attributes and behavioral characteristics of environmental knowledge. Third, in conjunction with the company's green transformation practices, the items were semantically revised to better reflect employees' daily work scenarios, as shown in table 2.

Table 2. Initial Items and Pretest Evidence

Definitions	Questionnaire items	Behavioral content	IOC	CITC	α
Environmental knowledge contribution (EKC) refers to employees' proactive provision of environmental experiences, information, suggestions, and practices to others, thereby transforming personal environmental knowledge into shared organizational resources.	EKS1: I proactively share my work experience related to environmental improvement.	Sharing environmental-improvement experience	1.00	0.753	0.845
	EKS2: I provide colleagues with suggestions on energy conservation and emission reduction.	Providing energy-saving suggestions	1.00	0.729	
	EKS3: I explain green operating procedures and environmental-management standards to others.	Explaining green procedures and standards	0.80	0.686	
	EKS4: I encourage team members to share environmental knowledge.	Encouraging team knowledge exchange	0.80	0.565	
Environmental knowledge acquisition (EKA) refers to employees' active efforts to seek, learn, collect, and absorb environmental-management knowledge from colleagues, organizational sources, and external sources.	EKS5: I proactively learn environmental-management methods from others.	Learning environmental-management methods	1.00	0.777	0.881
	EKS6: I ask colleagues about their experience with green-improvement programs.	Seeking green-improvement experience	0.80	0.738	
	EKS7: I follow and collect information about new environmental technologies and green practices.	Collecting environmental technology and practice information	1.00	0.736	
	EKS8: I proactively learn about the organization's environmental policies and green standards.	Learning organizational policies and standards	0.80	0.714	
Environmental knowledge integration (EKI) refers to combining, interpreting, and translating environmental knowledge from	EKS9: I integrate environmental suggestions from different sources.	Integrating suggestions from different sources	0.80	0.479	0.850

different sources into a coherent work-relevant understanding that supports subsequent application, while remaining distinct from downstream knowledge application and organizational outcomes.	EKS10: I apply the green knowledge I have acquired to my work.	Incorporating acquired environmental knowledge into work	1.00	0.778
	EKS11: I facilitate the integration of environmental experience within the team.	Combining team environmental experience	1.00	0.769
	EKS12: I translate external green information into internal process practices.	Translating external information into internally usable practices	0.80	0.749

3.2. Expert Review and Content Validation

Content validity was assessed by five experts: two green-management scholars, one organizational behavior and human resource management scholar, and two environmental-management practitioners. Item relevance was coded as 1 (relevant), 0 (uncertain), or −1 (not relevant). All 12 items achieved an index of item-objective congruence of at least 0.80, exceeding the 0.60 retention criterion. The experts recommended reducing slogan-like wording, improving behavioral observability, and emphasizing environmental knowledge to distinguish the items from general work knowledge or green attitudes. Accordingly, minor wording revisions were made. For example, "I support team discussions about environmental protection concepts" was revised to "I encourage team members to share environmental protection knowledge," while "I focus on green development information" was refined to "I focus on and collect information on new environmental protection technologies and green practices."

3.3. Pretest

A pretest was conducted from January 6 to February 5, 2026, with 80 employees from construction, manufacturing, logistics, transportation, and related productive-service enterprises. Respondents evaluated wording clarity and answered the 12 items on a five-point agreement scale from 1 (strongly disagree) to 5 (strongly agree). Dimension-level Cronbach's alpha coefficients exceeded 0.80, and corrected item-total correlations exceeded 0.30. Respondents identified EKS9 as comparatively abstract, so it was retained only for formal exploratory evaluation rather than assumed to be valid a priori. The pretest supported proceeding to formal analysis but did not determine the final item set. Expert relevance, corrected item-total correlations, respondent feedback, and formal factor performance were treated as complementary evidence.

3.4. Formal Survey and Sample Allocation

Formal survey data were collected through Wenjuanxing from February 10 to April 10, 2026. The target population comprised employees of registered construction enterprises in Hainan Province, China, involved in green transformation, environmental-management improvement, or related practices. Using the official provincial enterprise registry as the sampling frame, 150 enterprises were selected through simple random sampling. Five questionnaires were distributed to eligible employees in each enterprise with organizational assistance, totaling 750 questionnaires. Participation was voluntary and anonymous. Respondents were informed of the study purpose, confidentiality provisions, and right to withdraw, and questionnaire submission constituted electronic informed consent. Of the 750 questionnaires, 652 were returned, yielding an 86.9% response rate. Data screening excluded 34 responses with missing core-item data, invariant response patterns, or logical inconsistencies. The final sample comprised 618 valid responses, equivalent to 82.4% of distributed and 94.8% of returned questionnaires. For analytical cross-validation, the 618 valid cases were randomly allocated using a computer-generated random-number procedure in SPSS 27.0. The resulting mutually exclusive subsamples comprised 302 respondents for exploratory factor analysis and item purification and 316 different respondents for confirmatory factor analysis and measurement-model assessment. No respondent appeared in both subsamples. Table 3 reports the demographic and organizational characteristics of the EFA sample, CFA sample, and total sample.

Table 3. Descriptive statistics of sample characteristics

Characteristic	Category	EFA sample (n = 302)	CFA sample (n = 316)	Total sample (N = 618)
Gender	Male	149 (49.34%)	137 (43.35%)	286 (46.28%)
	Female	153 (50.66%)	179 (56.65%)	332 (53.72%)

Age group	18–29 years	51 (16.89%)	49 (15.51%)	100 (16.18%)
	30–39 years	115 (38.08%)	118 (37.34%)	233 (37.70%)
	40 years or older	136 (45.03%)	149 (47.15%)	285 (46.12%)
Education	College or below	106 (35.10%)	109 (34.50%)	215 (34.79%)
	Bachelor's degree	156 (51.66%)	157 (49.68%)	313 (50.65%)
	Postgraduate degree	40 (13.24%)	50 (15.82%)	90 (14.56%)
Job category	Frontline or on-site operations	111 (36.76%)	120 (37.98%)	231 (37.38%)
	Technical or professional support	82 (27.15%)	84 (26.58%)	166 (26.86%)
	Administrative or functional positions	63 (20.86%)	64 (20.25%)	127 (20.55%)
	Supervisory or management positions	46 (15.23%)	48 (15.19%)	94 (15.21%)
Work years	Less than 5 years	128 (42.38%)	116 (36.71%)	244 (39.48%)
	5–10 years	116 (38.41%)	136 (43.04%)	252 (40.78%)
	More than 10 years	58 (19.21%)	64 (20.25%)	122 (19.74%)
Firm size	Fewer than 500 employees	136 (45.03%)	130 (41.14%)	266 (43.04%)
	500–999 employees	77 (25.50%)	81 (25.63%)	158 (25.57%)
	1,000 employees or more	89 (29.47%)	105 (33.23%)	194 (31.39%)
Ownership	State-owned enterprise	126 (41.72%)	136 (43.04%)	262 (42.39%)
	Non-state-owned enterprise	176 (58.28%)	180 (56.96%)	356 (57.61%)
Environmental certification	Yes	174 (57.62%)	197 (62.34%)	371 (60.03%)
	No	128 (42.38%)	119 (37.66%)	247 (39.97%)
Green-work participation	Yes	200 (66.23%)	221 (69.94%)	421 (68.12%)
	No	102 (33.77%)	95 (30.06%)	197 (31.88%)

3.5. Data Analysis Strategy

Descriptive statistics, reliability analysis, Harman's single-factor test, and exploratory factor analysis (EFA) were conducted in SPSS 27.0. EFA used principal-axis factoring with Promax rotation because the dimensions were expected to correlate [23]. Factor retention was guided by parallel analysis using 1,000 raw-data permutations and the 95th-percentile criterion, alongside scree-plot inspection and theoretical interpretability [24]. Item assessment considered pattern coefficients, cross-loadings, loading separation, communalities, theoretical relevance, and content coverage. General thresholds were primary loadings of approximately 0.50 or higher, cross-loadings below 0.40, loading separation of at least 0.20, and communalities of approximately 0.40 or higher [25]. Confirmatory factor analysis and alternative measurement-model comparisons were performed using covariance-based structural equation modeling in SmartPLS 4 with maximum-likelihood estimation [26].

The final 10-item structure identified in the calibration subsample was specified before analysis of the independent 316-case validation subsample. Model fit was evaluated using chi-square and degrees of freedom, the comparative fit index, Tucker–Lewis index, root mean square error of approximation, and standardized root mean square residual. Comparative fit index and Tucker–Lewis index values of 0.90 or higher and root mean square error of approximation and standardized root mean square residual values below 0.08 were regarded as indicating acceptable fit [27]. No correlated residuals were specified. Internal consistency was evaluated using Cronbach's alpha and composite reliability, with values of .70 or higher considered acceptable. Convergent validity was assessed using average variance extracted, with values of .50 or higher indicating adequate convergence. Discriminant validity was evaluated using factor correlations, the Fornell–Larcker criterion [28], and heterotrait–monotrait ratios, with HTMT values below .85 used as a conservative guideline [29]. The statistics were calculated as follows:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_T^2}\right) \quad (1)$$

$$CR = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum \theta_i} \quad (2)$$

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum \theta_i} \quad (3)$$

$$HTMT_{ab} = \frac{\text{mean}\left(\left|r_{a_i b_j}\right|\right)}{\sqrt{\text{mean}\left(\left|r_{a_i a_k}\right|\right)\text{mean}\left(\left|r_{b_j b_l}\right|\right)}}. \quad (4)$$

*k denotes the number of items, σ_i^2 denotes item variance, σ_T^2 denotes total-score variance, λ_i denotes a standardized loading, θ_i denotes measurement-error variance, and r denotes the relevant item correlation.

3.6. Common Method Bias: Procedural and Statistical Controls

Because the data were collected using self-report questionnaires, procedural and statistical measures were used to reduce and assess potential common method bias [30]. Participation was voluntary and anonymous, respondents were informed that there were no correct or incorrect answers, and response confidentiality was emphasized. Questionnaire instructions used clear and neutral wording, and items representing different dimensions were interspersed to reduce respondents' ability to infer the hypothesized structure. Statistically, Harman's single-factor test, and a single-factor confirmatory model were used as diagnostic checks. These procedures were not treated as conclusive tests capable of excluding all method variance. Instead, they were used to assess whether one dominant general factor accounted for the covariance among the retained items. The limitations of these diagnostics were considered when interpreting the results.

4. Results and Discussion

4.1. Exploratory Factor Analysis

Exploratory factor analysis was conducted using the 302-case calibration sample, with principal-axis factoring and Promax oblique rotation (κ = 4). The initial 12-item correlation matrix was suitable for factor analysis, as indicated by a KMO measure of 0.869 and a statistically significant Bartlett's test of sphericity, $\chi^2(66) = 1{,}846.335$, $p < 0.001$. Parallel analysis based on 1,000 raw-data permutations and the 95th-percentile criterion supported a three-factor structure. Items were screened sequentially using their pattern coefficients, cross-loading, loading separation, communalities, theoretical consistency, and content coverage. EKS4 loaded more strongly on environmental knowledge acquisition (0.480) than on its intended environmental knowledge contribution factor (0.383), with a loading separation of only 0.097. EKS4 was therefore removed. After the factor analysis was re-estimated, EKS9 continued to show a weak loading on environmental knowledge integration (0.372), essentially unchanged from its initial loading of 0.374, and was subsequently removed. Parallel analysis repeated after each deletion continued to support three factors. For the final 10-item set, the first three raw-data eigenvalues (3.895, 1.220, and 1.148) exceeded the corresponding 95th-percentile random eigenvalues (0.423, 0.302, and 0.220), whereas the fourth raw-data eigenvalue (0.014) was lower than its random counterpart (0.149).

The final correlation matrix demonstrated satisfactory factorability, with a Kaiser–Meyer–Olkin measure of 0.831 and a statistically significant Bartlett's test of sphericity, $\chi^2(45) = 1{,}548.865$, $p < 0.001$. The three-factor solution accounted for 65.771% of the variance. As shown in table 4, all retained items loaded on their intended factors, with pattern coefficients ranging from 0.702 to 0.860 and communalities ranging from 0.521 to 0.732. No cross-loading pattern reached 0.30. Interfactor correlations ranged from 0.337 to 0.436, indicating that the dimensions were related but distinguishable. The final solution comprised environmental knowledge contribution (EKS1–EKS3), environmental knowledge acquisition (EKS5–EKS8), and environmental knowledge integration (EKS10–EKS12) and was retained for confirmatory factor analysis.

Table 4. Pattern Coefficients and Communalities for the Final Three-Factor EFA Solution

Item	EKC	EKA	EKI	h^2
EKS1	0.837			0.698
EKS2	0.807			0.637
EKS3	0.702			0.521
EKS5		0.850		0.712
EKS6		0.739		0.579
EKS7		0.821		0.656
EKS8		0.757		0.590
EKS10			0.842	0.731

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EKS11	0.847	0.732
EKS12	0.860	0.720

4.2. Confirmatory Factor Analysis

Confirmatory factor analysis was conducted using the CB-SEM module in SmartPLS 4 with maximum-likelihood estimation. The independent 316-case validation subsample was used to evaluate the 10-item, three-factor structure identified through exploratory factor analysis. Each item was specified to load only on its theoretically intended factor, the three latent factors were allowed to correlate, and no correlated residuals were specified, as shown in figure 2. The hypothesized three-factor model showed satisfactory fit to the validation data, $\chi^2(32) = 36.672$, $p = 0.261$, $\chi^2/df = 1.146$, CFI = 0.999, TLI = 0.998, RMSEA = 0.015, and SRMR = 0.019. As shown in Figure 2, all standardized factor loadings were statistically significant and ranged from 0.765 to 0.885. The loadings ranged from 0.765 to 0.850 for environmental knowledge contribution, from 0.772 to 0.852 for environmental knowledge acquisition, and from 0.832 to 0.885 for environmental knowledge integration. Latent-factor correlations ranged from 0.367 to 0.423, indicating that the three dimensions were related but empirically distinguishable. These results provided support for the proposed 10-item, three-factor measurement model in the non-overlapping CFA validation subsample.

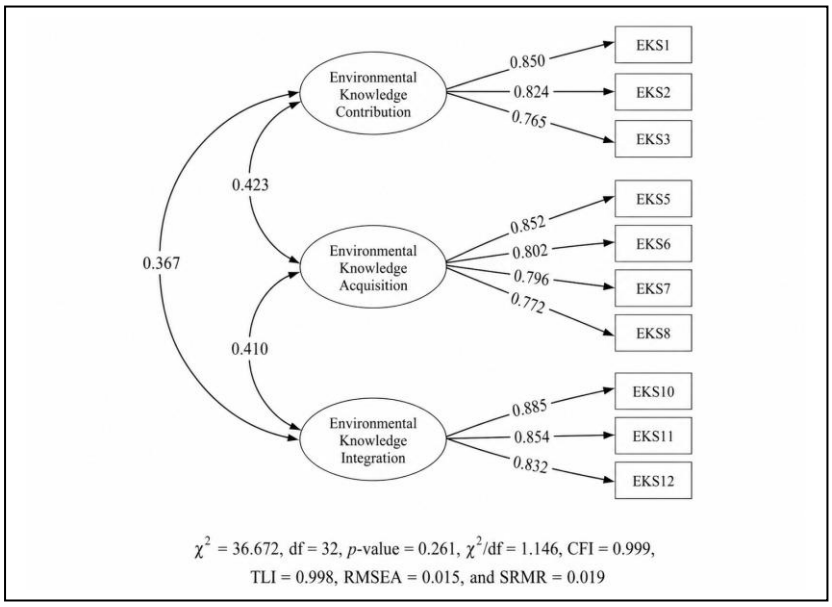


Figure 2. Standardized Estimates for the Final Three-Factor Confirmatory Measurement Model

4.3. Reliability and Construct Validity

As shown in table 5, Cronbach's alpha values for environmental knowledge contribution, environmental knowledge acquisition, and environmental knowledge integration were 0.854, 0.881, and 0.893, respectively. The corresponding composite reliability values were 0.854, 0.881, and 0.893, all exceeding the recommended threshold of 0.70. Convergent validity was also supported. The average variance extracted values were 0.662 for environmental knowledge contribution, 0.650 for environmental knowledge acquisition, and 0.735 for environmental knowledge integration, all above 0.50. These results indicated that each latent factor explained a satisfactory proportion of the variance in its indicators. Discriminant validity was assessed using the Fornell–Larcker criterion and heterotrait–monotrait ratios. The square roots of AVE were 0.814, 0.806, and 0.857 for environmental knowledge contribution, environmental knowledge acquisition, and environmental knowledge integration, respectively. Each value exceeded the corresponding maximum interconstruct correlation (0.423, 0.423, and 0.410). In addition, all HTMT values were below 0.85, with the maximum value being 0.422. Taken together, these results supported the reliability, convergent validity, and discriminant validity of the final three-factor scale.

Table 5. Construct validity and reliability of the final CFA measurement model.

Latent factors/questions	Standardized loading	R^2	Cronbach's α	CR	AVE	$\sqrt{AVE}$	Highest correlation	Highest HTMT
EKC			0.854	0.854	0.662	0.814	0.423	0.422

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EKS1	0.850	0.723						
EKS2	0.824	0.679						
EKS3	0.765	0.585						
EKA								
EKS5	0.852	0.726						
EKS6	0.802	0.643	0.881	0.881	0.650	0.806	0.423	0.422
EKS7	0.796	0.634						
EKS8	0.772	0.596						
EKI								
EKS10	0.885	0.783	0.893	0.893	0.735	0.857	0.410	0.406
EKS11	0.854	0.729						
EKS12	0.832	0.692						

* Standardized factor loadings were significant at $p < 0.001$. Cronbach's α and CR ≥ 0.70, AVE ≥ 0.50, $\sqrt{AVE}$ greater than the corresponding inter-construct correlations, and HTMT < 0.85 indicate satisfactory measurement quality.

4.4. Common Method Bias Assessment

Because the data were collected using self-report questionnaires, common method bias was assessed using Harman's single-factor test and a single-factor confirmatory model. Harman's test indicated that the first unrotated factor had an eigenvalue of 4.424 and accounted for 44.243% of the total variance, below the commonly used 50% criterion. In addition, the single-factor confirmatory model demonstrated substantially poorer fit than the hypothesized three-factor model, as reported in table 6. These diagnostic results did not indicate that one general factor dominated the covariance among the retained items. Nevertheless, Harman's test and single-factor model comparison cannot exclude all forms of common method variance, and the results should be interpreted in light of the single-source, self-report design.

Table 6. Fit of the Hypothesized and Alternative Measurement Models

Model	χ^2/df	CFI	TLI	RMSEA	SRMR
Single-factor model	45.612	0.540	0.409	0.269	0.170
Two-factor model A: EKC+EKA	21.158	0.798	0.733	0.181	0.124
Two-factor model B: EKC+EKI	22.976	0.780	0.709	0.189	0.144
Two-factor model C: EKA+EKI	28.222	0.727	0.639	0.210	0.136
Correlated three-factor model	1.146	0.999	0.998	0.015	0.019

* Acceptable model fit was indicated by χ^2/df < 3.00, CFI and TLI > 0.90, and RMSEA and SRMR < 0.08.

4.5. Comparison of Alternative Models

To further evaluate the distinctiveness of the three dimensions, the hypothesized correlated three-factor model was compared with four alternative measurement models using the same 316-case validation sample and the same final 10 items. In the single-factor model, all items were specified to load on one common factor. In the three two-factor models, environmental knowledge contribution and environmental knowledge acquisition, environmental knowledge contribution and environmental knowledge integration, or environmental knowledge acquisition and environmental knowledge integration were combined, while the remaining dimension was modeled separately.

As shown in Table 6, the single-factor model and all three two-factor models exhibited poor fit to the data. In contrast, the correlated three-factor model demonstrated prespecified fit, with χ^2/df = 1.146, CFI = 0.999, TLI = 0.998, RMSEA = 0.015, and SRMR = 0.019. The three-factor model therefore fitted the data substantially better than all competing models. These findings indicated that environmental knowledge contribution, environmental knowledge acquisition, and environmental knowledge integration represented related but empirically distinct dimensions and should not be combined into either a single factor or any of the tested two-factor structures.

5. Discussion

5.1. Sharing Interpretation of the Three-Factor Structure

The findings support a three-dimensional structure of environmental knowledge sharing comprising environmental knowledge contribution, environmental knowledge acquisition, and environmental knowledge integration. The three-factor model met the prespecified fit criteria and fitted the validation data substantially better than the tested one- and

two-factor alternatives, supporting the distinction among the three dimensions in the present validation sample. These results should nevertheless be interpreted as evidence for the specified measurement model in the present validation sample rather than as evidence of measurement invariance or cross-context generalizability. Environmental knowledge sharing is therefore represented in this study as three related but distinguishable processes through which employees contribute, acquire, and integrate environmental knowledge.

Environmental knowledge contribution and acquisition correspond to the two fundamental directions of knowledge flow identified in general knowledge-sharing research. Contribution reflects employees' willingness to provide environmental experience, green practices, and improvement suggestions to others, whereas acquisition reflects employees' efforts to seek, collect, and absorb environmental knowledge. These findings are consistent with the distinction between knowledge donating and knowledge collecting proposed in previous studies [18, 19]. However, the environmental context gives these two dimensions more specific content, including environmental standards, energy conservation practices, green technologies, and pollution-prevention experience.

More importantly, environmental knowledge integration emerged as an independent dimension. Traditional knowledge-sharing frameworks often emphasize the exchange of knowledge but pay less attention to what happens after knowledge has been contributed or acquired. The present findings indicate that, in organizational green transformation, knowledge sharing is incomplete unless environmental knowledge is combined, jointly interpreted, and internalized in work processes. This result is consistent with the knowledge-based view, which emphasizes that organizational value derives not only from possessing knowledge but also from integrating and applying it [1]. It also corresponds with research suggesting that green knowledge integration connects organizational learning with green innovation and capability development [13], [31]. The three dimensions therefore represent a process of environmental knowledge flow from output to input and transformation. Employees first contribute and acquire environmental knowledge, while integration enables that knowledge to develop into a coordinated working understanding that can inform subsequent green practices.

5.2. Item Purification and Construct Boundaries

The sequential removal of EKS4 and EKS9 clarified the empirical and conceptual boundaries of the scale. EKS4 ("I encourage team members to share environmental knowledge") loaded more strongly on environmental knowledge acquisition (0.480) than on its intended contribution factor (0.383), with a loading separation of only 0.097. This item may capture facilitation of others' knowledge exchange rather than the respondent's own knowledge contribution and was therefore removed. After re-estimation, EKS9 ("I integrate environmental suggestions from different sources") continued to show a weak loading on environmental knowledge integration (0.372; initial loading = 0.374). Its reference to "different sources" may have been too abstract to represent a consistent observable behavior, and the item was subsequently removed. Both deletions occurred during the exploratory stage; the independent CFA therefore evaluated a prespecified 10-item structure without further item deletion.

The final EKC and EKI dimensions each retained three indicators. Although three indicators are sufficient for latent-factor identification, their adequacy also depends on whether they preserve meaningful construct coverage. For EKC, the retained items represent sharing environmental experience (EKS1), providing environmental suggestions (EKS2), and explaining environmental procedures (EKS3). For EKI, they represent incorporating acquired environmental knowledge into work (EKS10), integrating team environmental experience (EKS11), and translating external environmental information into internally usable practices (EKS12). Thus, the retained indicators capture differentiated behavioral aspects of each proposed dimension rather than redundant expressions of a single behavior. Their standardized loadings (0.765–0.885), communalities, composite reliability, and AVE further support the internal quality of the retained indicators. Nevertheless, these psychometric results do not by themselves establish exhaustive content coverage. Further qualitative item development and independent validation are therefore needed to assess whether additional behaviorally specific indicators can broaden construct coverage without reintroducing the ambiguity identified in EKS4 and EKS9. The interpretation of environmental knowledge integration requires attention to its boundary with knowledge application. Prior research conceptualizes knowledge integration as the synthesis and transformation of acquired knowledge that can support subsequent application [1], [32], while integration and application have also been modeled as related but distinguishable knowledge processes [33]. Accordingly, the present

study interprets EKI as the transformation of acquired and exchanged environmental knowledge into a coherent work-relevant understanding rather than as a downstream organizational outcome.

This distinction is particularly relevant to EKS10 ("I apply the green knowledge I have acquired to my work"), which lies close to the boundary between integration and application. In the present scale, EKS10 reflects the immediate incorporation of acquired environmental knowledge into work, while EKS12 reflects its translation into internally usable practices. Neither item directly assesses downstream outcomes such as green innovation or sustainable performance. Empirically, the three-factor CFA, discriminant-validity assessment, and alternative-model comparisons support the distinction of EKI from environmental knowledge contribution and acquisition. However, because the survey did not include a separate measure of knowledge application or utilization, direct discriminant validity between these constructs was not tested. The present evidence therefore supports EKI as a distinct dimension within the proposed three-factor scale, while its empirical boundary with knowledge application requires further validation.

5.3. Comparison with Previous Measurement Approaches

The results both support and extend existing knowledge-sharing measurement approaches. Previous studies commonly conceptualize knowledge sharing as contribution and acquisition [19], [20]. The present study confirms the relevance of these two dimensions but shows that this traditional structure may be insufficient for organizational green transformation. Environmental knowledge differs from general work knowledge because it often involves technical standards, environmental regulations, operational procedures, and cross-functional practices. Merely sharing or obtaining such knowledge does not ensure that it will influence organizational behavior. Environmental knowledge must also be translated into internal procedures, team practices, and green improvement activities. The independent identification of environmental knowledge integration therefore captures the transition from information exchange to shared working understanding. The scale also differs from broader green knowledge management measures. Green knowledge management may include organizational systems for knowledge creation, storage, dissemination, and application, whereas the present scale focuses specifically on employee-level sharing behaviors. The final ten-item scale therefore provides a concise and context-sensitive measure of how employees contribute, acquire, and integrate environmental knowledge during organizational green transformation. Overall, the findings indicate that environmental knowledge contribution, acquisition, and integration are theoretically connected but empirically distinguishable. This three-dimensional structure provides a more complete representation of the employee-level knowledge processes underlying organizational green transformation.

6. Implications

6.1. Theoretical Implications

This study advances the conceptualization of environmental knowledge sharing by specifying its content, behavioral direction, and transformation process. Unlike generic knowledge sharing, it concerns environmental standards, green technologies, operating procedures, and improvement practices. The study extends the conventional contribution–acquisition framework by identifying environmental knowledge integration as a related but distinct dimension. Integration involves comparing, combining, jointly interpreting, and internalizing exchanged knowledge to develop a coherent, work-relevant understanding that supports subsequent application. Integration is not defined by downstream outcomes such as green innovation, organizational capability, or sustainable performance. This distinction separates knowledge-sharing processes from their potential consequences. Methodologically, the study applies construct specifications, expert review, pretesting, sequential item purification, parallel analysis, and confirmatory validation using a non-overlapping subsample. The resulting 10-item scale provides a concise instrument for examining how employees contribute, acquire, and integrate environmental knowledge and supports future research on its antecedents, outcomes, and boundary conditions.

6.2. Practical Implications

The scale can help organizations determine whether weaknesses in environmental knowledge sharing stem from limited contribution, insufficient acquisition, or inadequate integration. Because these dimensions represent distinct processes, interventions should target the specific area requiring improvement rather than rely on a general knowledge-sharing initiative. Contribution can be supported through green suggestion systems, project reviews, communities of practice, and documentation of frontline experience. Acquisition can be strengthened through peer learning, cross-project

exchanges, environmental training, and access to current regulatory and technological information. Integration can be encouraged through cross-functional sessions that compare information, resolve conflicting interpretations, and develop a shared understanding of environmental issues. The scale should be used as a developmental and research diagnostic, not as a direct measure of green performance or for high-stakes employee evaluation. Its scores reflect knowledge-sharing processes rather than evidence of achieved green innovation or sustainable performance. Because both non-overlapping EFA and CFA samples were drawn from registered construction enterprises in Hainan Province, China, generalizability remains limited. Future studies should test measurement invariance across demographic and organizational groups and replicate the scale using independent samples from other industries, regions, and countries.

7. Conclusion

This study developed and initially validated a 10-item Environmental Knowledge Sharing Scale for organizational green transformation. Expert review, pretesting, EFA using a 302-case calibration sample, and CFA using a non-overlapping 316-case validation sample supported three related but distinct dimensions: environmental knowledge contribution, acquisition, and integration. The final scale comprises three contributions, four acquisition, and three integration items, with satisfactory reliability and construct validity. 4The scale conceptualizes environmental knowledge sharing as employees providing environmental knowledge, acquiring it from others and organizational sources, and transforming exchanged knowledge into a shared working understanding. It offers a more precise basis for examining employee-level knowledge processes during green transformation. Future research should test measurement invariance, criterion-related and predictive validity, replicability across organizational and cultural contexts, and discriminant validity relative to knowledge application and utilization.

8. Limitations and Future Research

Several limitations define the scope of this initial validation. First, although non-overlapping EFA and CFA subsamples enabled internal cross-validation, both comprised employees of registered construction enterprises in Hainan Province, China, and measurement invariance was not tested. Future studies should examine invariance across demographic and organizational groups and replicate the scale using independently recruited samples from other industries, regions, and countries. Second, the cross-sectional, single-source self-report design remains susceptible to common method variance and social-desirability bias despite the procedural and statistical controls applied. Longitudinal, multi-wave, and multi-source designs, together with marker-variable or latent method-factor approaches, are recommended. Third, the study focused on internal psychometric validation without testing criterion-related, nomological, or predictive validity. Future research should examine relevant antecedents and outcomes, including green leadership, green human resource management, employee green behavior, green innovation, and sustainable performance. The discriminant validity of environmental knowledge integration against knowledge application or utilization should also be assessed using separate, simultaneous measures [32], [33]. Finally, item purification retained only three indicators each for environmental knowledge contribution and integration. Although their loadings, reliability, and convergent validity were satisfactory, further qualitative item development and independent validation are needed to improve construct coverage without introducing ambiguity.

9. Declarations

9.1. Author Contributions

Conceptualization: K.M., S.I., S.W.; Methodology: K.M., S.I., S.W.; Software: K.M., S.I.; Validation: K.M.; Formal Analysis: K.M.; Investigation: S.I., S.W.; Resources: K.M., S.W.; Data Curation: S.I.; Writing – Original Draft Preparation: K.M., S.I., S.W.; Writing – Review and Editing: K.M., S.I., S.W.; Visualization: K.M.; All authors have read and agreed to the published version of the manuscript.

9.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

9.4. Institutional Review Board Statement

Not applicable.

9.5. Informed Consent Statement

Not applicable.

9.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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