



SUSTAINABILITY CONSCIOUSNESS AMONG STEM EDUCATORS AND ITS LINKS TO AGRICULTURAL AND CLIMATE CHANGE AWARENESS

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Abstract. *Global climate and food security crises make sustainability competencies among STEM educators increasingly critical. This study examined structural relationships among science and mathematics teachers' sustainability consciousness, climate change awareness, and agricultural awareness. Using a correlational survey design, data from 482 teachers in eastern Türkiye were analysed through structural equation modelling and multi-group confirmatory factor analysis. The sample comprised 269 science teachers and 213 mathematics teachers. Results showed that sustainability consciousness positively and significantly predicted both climate change and agricultural awareness, and that climate change awareness partially mediated the effect on agricultural awareness. Although overall awareness levels clustered in the moderate range, the pedagogical competence and classroom implementation dimensions for agricultural topics remained low, indicating a gap between cognitive readiness and practice. Multi-group confirmatory factor analyses supported measurement invariance across science and mathematics teachers. Overall, teachers can conceptually connect climate and agriculture issues, yet they lack the procedural and pedagogical tools to enact this knowledge in classrooms ("Green in Theory, Brown in Practice"). Teacher education should therefore move beyond raising environmental knowledge and systematically strengthen pedagogical content knowledge with practice-based training for climate–agriculture instruction.*

Keywords: *agricultural awareness, climate change awareness, STEM education, structural equation modelling, sustainability consciousness*

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Introduction

We argue that STEM teachers' awareness of climate change and agriculture should be examined in relation to their sustainability consciousness. The interdependence of climate and food systems provides a rationale for examining these constructs together (Vermeulen et al., 2012). International frameworks support sustainability education and climate awareness (United Nations, 2015; United Nations Framework Convention on Climate Change, 2015; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020). However, how teachers' broader sustainability orientations relate to these specific domains requires empirical examination. Mochizuki and Bryan (2015) have advocated situating climate change education within education for sustainable development, providing a basis for this integrated perspective.

Science and mathematics offer complementary opportunities to connect environmental processes with quantitative reasoning. Previous work has addressed disciplinary integration in STEM education and sustainability in mathematics teacher education (English, 2016; Su et al., 2023). Ozdinc and Ceyhan (2024) have also presented a gamified STEM activity addressing climate change. These educational connections raise a question about teachers themselves: whether sustainability consciousness is associated with awareness of both climate change and agriculture. Examining science and mathematics teachers together also requires attention to whether these constructs are measured comparably across disciplines.

Türkiye provides a relevant context because climate-related agricultural vulnerability makes the connection between these domains locally consequential (Intergovernmental Panel on Climate Change [IPCC], 2023; Karahasan & Pinar, 2023). Ozturk et al. (2026) have examined the alignment of Turkish curricular objectives with international sustainability learning objectives. Complementing this curricular perspective, the present study examined the relationships among teachers' sustainability consciousness, climate change awareness, and agricultural awareness.



Sustainability Consciousness

Sustainability consciousness provides a broad orientation for examining domain-specific awareness. Gericke et al. (2019) have conceptualised it as encompassing knowingness, attitudes, and behaviours across environmental, social, and economic dimensions. Research using this framework has examined sustainability consciousness in relation to educational experiences and learner characteristics (Berglund et al., 2014; Olsson & Gericke, 2016). Its relevance to the present study lies in bringing these dimensions together when examining teachers' responses to climate and agricultural issues.

Previous studies have identified disciplinary and professional differences in teachers' understandings of sustainability and contributions to sustainability education (Borg et al., 2014; Sund & Gericke, 2020). Research with prospective science teachers has also examined how sustainable development is understood (Gunduz et al., 2024). Nevertheless, conceptual understanding does not necessarily demonstrate procedural knowledge or teaching competence. Richter-Beuschel and Bögeholz (2020) have distinguished conceptual from procedural knowledge in relation to sustainable land use. Debrah et al. (2021) have likewise considered knowledge, attitudes, and educational practices in their review of waste-management education. Accordingly, the present study examined sustainability consciousness as a potential correlate of climate and agricultural awareness without treating it as direct evidence of classroom competence.

Climate Change Awareness

Climate change awareness connects a broad sustainability orientation with a specific environmental challenge affecting agriculture. Studies of teachers have identified gaps and variation in climate knowledge, beliefs, and understanding of scientific explanations (Herman et al., 2017; Plutzer et al., 2016; Seroussi et al., 2019). Research with secondary teachers has also examined climate awareness in different educational contexts (Dorji et al., 2021). In the present study, climate change awareness was assessed through awareness of causes, consequences, energy-related issues, and international responses, using the instrument developed by Deniz et al. (2021).

Awareness should nevertheless be distinguished from willingness to act and enacted behaviour. Studies with young people have examined environmental attitudes, climate concern, and willingness to act in relation to personal and contextual factors (Hermans & Korhonen, 2017; Stevenson et al., 2019; Tuncer et al., 2005). Research with prospective teachers and teacher–student samples has similarly addressed awareness alongside behavioural willingness or reported practices (Dal et al., 2015; Natalia et al., 2023). Studies of climate-related behaviour and institutional barriers have further highlighted the limitations of treating awareness as sufficient for action (Parry & Metzger, 2023; Venghaus et al., 2022). These distinctions informed the examination of climate awareness as a separate construct within the proposed model.

Agricultural Awareness

Agricultural awareness provides a domain in which teachers' sustainability orientations and climate understanding may intersect. Agricultural literacy research has addressed understanding of food production and agricultural systems alongside relevant skills, attitudes, and beliefs (Frick et al., 1991; Vallera & Bodzin, 2016). Studies with rural and urban pupils have identified limitations in agricultural understanding, supporting its relevance as an educational concern (Hess & Trexler, 2011; Meischner & Trexler, 2003).

For teachers, this concern extends to how agricultural topics are understood and incorporated into instruction. Previous studies have examined agricultural awareness activities, school-based agricultural teaching, and prospective teachers' agricultural knowledge (Akgul & Macaroglu, 2011; Cross & Kahn, 2018; Knobloch & Martin, 2002). Kovar and Ball (2013) have synthesised the broader agricultural literacy literature, while Wang et al. (2020) have examined climate knowledge, beliefs, and teaching practices among secondary agriculture teachers. Building on these connections, the present study assessed agricultural awareness in relation to both sustainability consciousness and climate change awareness among science and mathematics teachers.

The Structural Link Among Sustainability, Climate, and Agriculture

Systems thinking provides the rationale for examining the three constructs within a single model. It directs attention to relationships among environmental and social processes (Meadows, 2008). Wiek et al. (2011) have

identified systems thinking as a key sustainability competency, while West et al. (2020) have emphasised interdependencies through a relational approach to sustainability science. Applied to the present study, these perspectives suggest that teachers' broader sustainability consciousness may be positively associated with their awareness of both climate change and agriculture.

We therefore hypothesised that climate change awareness would statistically mediate the relationship between sustainability consciousness and agricultural awareness. A broader sustainability orientation may be associated with greater attention to climate processes, while awareness of those processes may be associated with recognising agricultural risks and dependencies. The reciprocal relationship between climate and food systems provides a substantive basis for this proposed connection (Vermeulen et al., 2012). These arguments informed the hypothesised direct and indirect paths without establishing a causal sequence.

Fischer et al. (2022) have highlighted the need for stronger conceptual integration in teacher education for sustainable development. Monroe et al. (2019) have synthesised evidence on effective climate change education strategies. Complementing this instructional research, the present study examined relationships among teacher attributes that may inform future educational interventions. Previous studies have also identified disciplinary differences in sustainability-related understanding and teaching contributions (Borg et al., 2014; Sund & Gericke, 2020). Measurement invariance was therefore examined separately to assess whether the constructs were measured comparably across science and mathematics teachers.

Research Purpose, Contributions, and Hypotheses

This study examined the direct and indirect relationships among sustainability consciousness, climate change awareness, and agricultural awareness among science and mathematics teachers in Türkiye. Specifically, it tested whether climate change awareness mediated the relationship between sustainability consciousness and agricultural awareness. It also assessed measurement invariance across the two disciplinary groups. The study contributes evidence on the relationships among these constructs and the comparability of their measurement models across disciplines. The structural paths represent hypothesised statistical relationships within a cross-sectional design. The measurement invariance analyses addressed measurement equivalence rather than equality of structural relationships. The following hypotheses were proposed:

- H1. Sustainability consciousness positively predicts climate change awareness.
- H1a. The measurement model comprising sustainability consciousness and climate change awareness is invariant across science and mathematics teachers.
- H2. Sustainability consciousness positively predicts agricultural awareness.
- H2a. The measurement model comprising sustainability consciousness and agricultural awareness is invariant across science and mathematics teachers.
- H3. Climate change awareness positively predicts agricultural awareness.
- H3a. The measurement model comprising climate change awareness and agricultural awareness is invariant across science and mathematics teachers.
- H4. Climate change awareness mediates the relationship between sustainability consciousness and agricultural awareness.

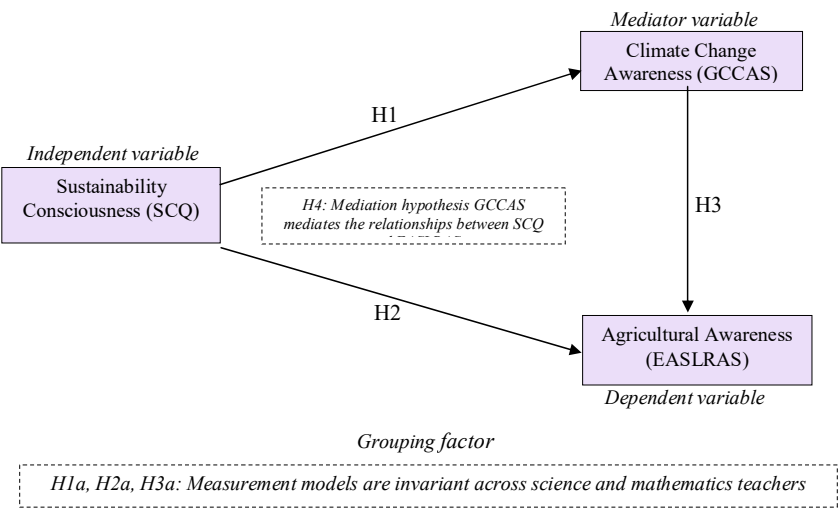
Research Methodology

Design

This study employed a quantitative, cross-sectional correlational design to examine the relationships among sustainability consciousness, climate change awareness, and agricultural awareness. Creswell and Creswell (2018) have conceptualised survey designs as approaches that describe a situation that existed in the past or exists at present in its natural context. They have also defined correlational surveys as approaches that examine the existence and degree of covariation between variables. Structural equation modelling was used to estimate the hypothesised direct and indirect relationships. Measurement invariance across science and mathematics teachers was examined using multi-group confirmatory factor analysis. Figure 1 presents the hypothesised model.



Figure 1
Research Design



Sample

The sample comprised 482 STEM educators, including science and mathematics teachers working in public lower secondary schools in a province in eastern Türkiye. To determine the study group, simple random sampling, a probability sampling method, was employed to enhance representativeness and minimise bias. Data were collected voluntarily, with informed consent from all participants. In forming the study group, the model's complexity and the statistical power required for Structural Equation Modelling (SEM) analyses were considered. In the literature, a sample size of 200 or more is considered sufficient to ensure the robustness of predictions from structural models (Kline, 2023). The final sample included 269 science teachers and 213 mathematics teachers. As participants were recruited from a single province in eastern Türkiye, the findings should be interpreted within this regional context. Table 1 presents the demographic characteristics of the participating teachers.

Table 1
Findings Regarding the Demographic Characteristics of the Sample

Variables	Discipline					
	Science Education		Mathematics Education		Total	
	N	%	N	%	N	%
Gender						
Male	172	63.9	142	66.7	314	65.1
Female	97	36.1	71	33.3	168	34.9
Education Status						
Bachelor's degree	207	77.0	172	80.8	379	78.6
Master's degree	62	23.0	41	19.2	103	21.4
Professional Seniority						
1-5 years	72	26.8	54	25.4	126	26.1
6-10 years	61	22.7	47	22.1	108	22.4
11-15 years	48	17.8	47	22.1	95	19.7



Variables	Discipline					
	Science Education		Mathematics Education		Total	
	N	%	N	%	N	%
16-20 years	40	14.9	25	11.7	65	13.5
21 years+	48	17.8	40	18.8	88	18.3
Total	269	100.0	213	100.0	482	100.0

As shown in Table 1, 55.8% of the participants were science teachers and 44.2% were mathematics teachers. Male teachers constituted 65.1% of the sample, and female teachers constituted 34.9%. Regarding educational background, 78.6% held a bachelor's degree and 21.4% held a master's degree. Regarding professional seniority, 26.1% of the teachers had 1-5 years of teaching experience, 22.4% had 6-10 years, 19.7% had 11-15 years, 13.5% had 16-20 years, and 18.3% had 21 years or more.

Instruments and Procedures

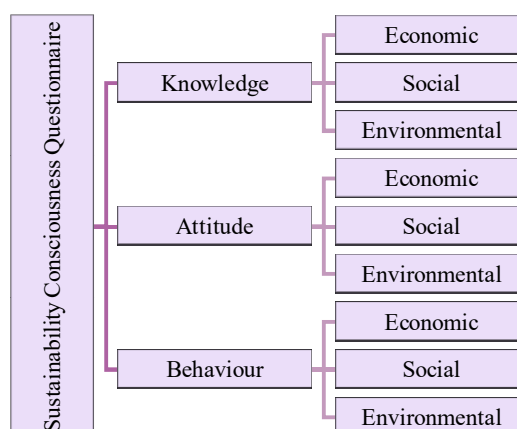
In this study, three separate measurement instruments were employed for data collection: the Sustainability Consciousness Scale, the Educators' Awareness and Sensitivity Levels Regarding Agriculture Scale, and the Global Climate Change Awareness Scale.

Sustainability Consciousness Questionnaire

In this study, to assess the levels of sustainability consciousness among STEM educators (science and mathematics teachers), the "Sustainability Consciousness Scale (SCQ)" developed by Michalos et al. (2012) and adapted into Turkish by Yuksel and Yildiz (2019) was used. This instrument, rated on a 5-point Likert scale and comprising 50 items, consists of three subscales: Knowledge, Attitude, and Behaviour. Each of these subscales, in turn, includes three hierarchical subdimensions: social, economic, and environmental (Figure 2).

Figure 2

Hierarchical Structure of the SCQ



Yuksel and Yildiz (2019) evaluated the Turkish adaptation using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) and reported an overall Cronbach's alpha of .860. In the present sample, the overall Cronbach's alpha was .962. In the Turkish adaptation study, the CFA fit indices for the Knowledge subscale were reported as $\chi^2/df = 4.92$, CFI = .92, IFI = .93, NFI = .93, and RMSEA = .064; for the "Attitude" subdimension as $\chi^2/df = 3.99$, CFI = .95, IFI = .94, NFI = .96, and RMSEA = .075; and for the "Behaviour" subdimension as $\chi^2/df = 4.97$, CFI = .92, IFI = .92, NFI = .91, and RMSEA = .084. In the present study, however, the corresponding values were $\chi^2/df = 0.99$,

CFI = 1.00, IFI = 1.00, NFI = .95, and RMSEA = .00 for the “Knowledge” subdimension; $\chi^2/df = 1.15$, CFI = .99, IFI = .99, NFI = .96, and RMSEA = .02 for the “Attitude” subdimension; and $\chi^2/df = 1.40$, CFI = .98, IFI = .98, NFI = .95, and RMSEA = .03 for the “Behaviour” subdimension. Overall, the fit indices indicated that the measurement model fitted the data well. The regression coefficients for the subdimensions are presented in Figures 3-5.

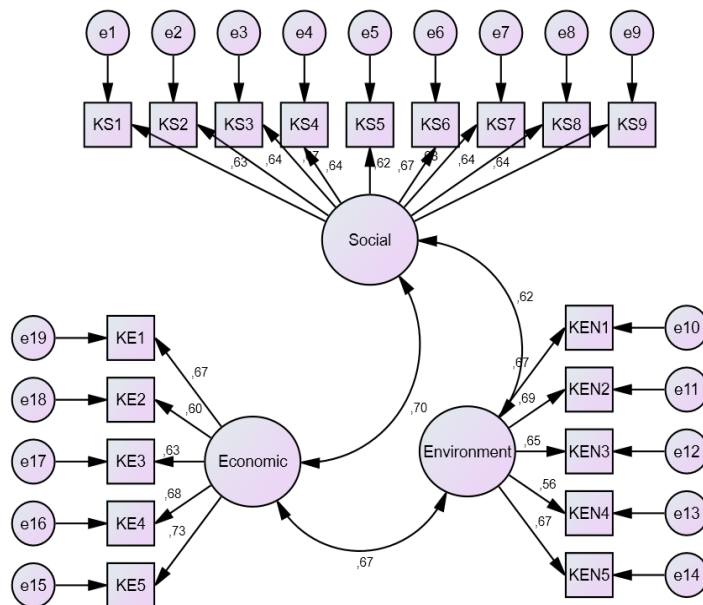
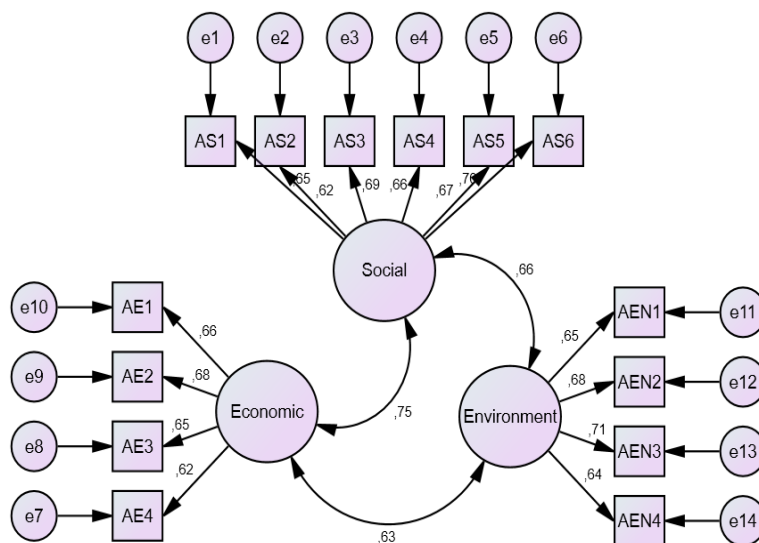
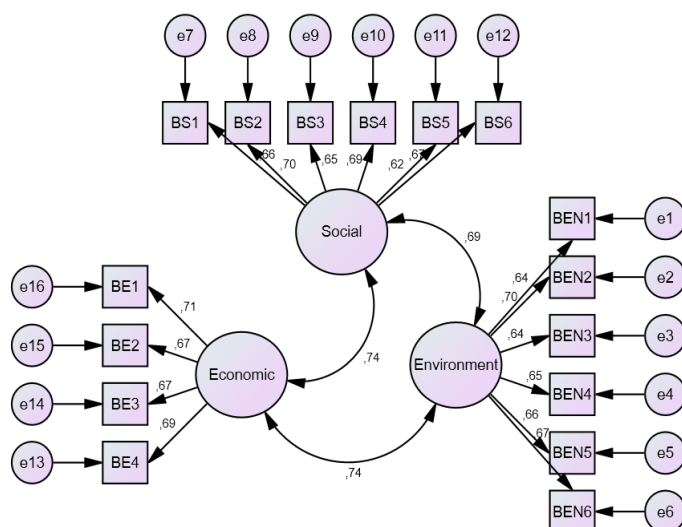
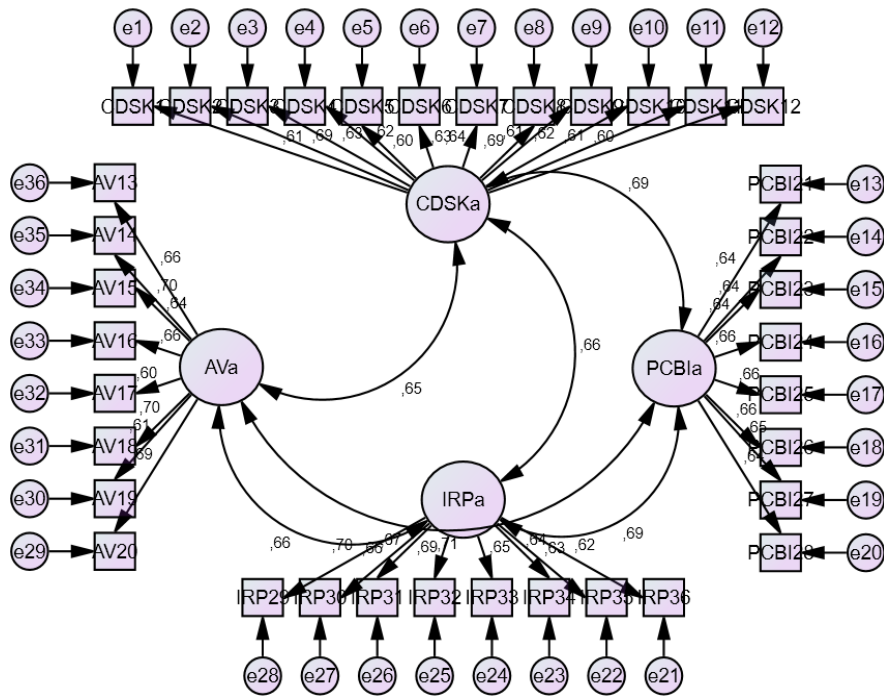
Figure 3*The Structural Model for the Knowledge Subdimension***Figure 4***The Structural Model for the Attitude Subdimension*

Figure 5*The Structural Model for the Behaviour Subdimension**Educators' Awareness and Sensitivity Levels Regarding Agriculture Scale*

In this study, participants' levels of agricultural awareness and sensitivity were assessed using the "Educators' Awareness and Sensitivity Levels Regarding Agriculture Scale (EASLRAS)" developed by the first and third authors. The scale development and full psychometric evaluation were conducted using an independent sample and reported in a separate article. Based on expert review and pilot testing with 186 science and mathematics teachers, a 36-item, 5-point Likert-type final form was obtained.

Construct validity was assessed through a two-stage procedure. First, EFA was conducted, followed by CFA on an independent sample of 211 science and mathematics teachers. The suitability of the data for factor analysis was supported by a Kaiser-Meyer-Olkin (KMO) coefficient of .865 and a statistically significant Bartlett's Test of Sphericity, $\chi^2 = 2472.363$, $p < .05$, indicating that the correlation matrix was factorable (Buyukozturk et al., 2016). EFA yielded a four-factor solution. Factor loadings for the first factor (Cognitive Domain and System Knowledge) ranged from .571 to .868 and accounted for 29.7% of the total variance; for the second factor (Attitudes and Values) from .584 to .757 (7.7% of the variance); for the third factor (Pedagogical Competence and Behavioural Intention) from .474 to .845 (7.2% of the variance); and for the fourth factor (Impact and Risk Perception) from -.409 to -.800, explaining an additional 5.6% of the variance.

CFA results indicated an overall good model fit. Given the sample size (< 250) and number of observed variables (12-30), recommended thresholds were $\chi^2/df < 2.5$, GFI > .90, CFI and TLI > .95, and RMSEA < .08 (Byrne, 2016). The tested model produced CFI = .96, TLI = .96, RMSEA = .04, SRMR = .06, and $\chi^2/df = 1.18$, all within the acceptable or good fit range (Kline, 2023). Internal consistency estimates were high, with Cronbach's alpha coefficients of .933 for Cognitive Domain and System Knowledge (CDSK), .853 for Impact and Risk Perception (IRP), .861 for Attitudes and Values (AV), .878 for Pedagogical Competence and Behavioural Intention (PCBI), and .933 for the overall scale, indicating robust reliability at both subscale and total-score levels. In the present study, the scale demonstrated excellent internal consistency (Cronbach's $\alpha = .941$). The CFA indicated that the model fit indices were $\chi^2/df = 1.05$, CFI = .99, IFI = .99, NFI = .91, and RMSEA = .01. These results indicated that the measurement model fitted the data well. The regression coefficients for the subdimensions are presented in Figure 6.

Figure 6*The Structural Model for the EASLRAS**Global Climate Change Awareness Scale*

In the study, the “Global Climate Change Awareness Scale (GCCAS)” developed by Deniz et al. (2021) was employed to determine STEM educators’ (science and mathematics teachers) levels of awareness regarding global climate change. This instrument, consisting of 21 items on a 5-point Likert scale, has a four-factor structure comprising “Impacts on Natural and Human-Made Environments (ENHE),” “The Relationship Between Causal Factors and Energy Consumption (ECR),” “Awareness of Global Organisations and Agreements (AGOA),” and “Causal Factors (RE).” The KMO value of .866 and the significant Bartlett’s Test of Sphericity ($p < .05$) confirmed the data’s suitability for factor analysis, while Cronbach’s α of .826 indicated good internal consistency. The CFA yielded the following fit indices $\chi^2/df = 2.33$; RMSEA = .05; IFI = .93; TLI = .93; CFI = .93; GFI = .91; AGFI = .89, and SRMR = .05. In the present study, the Cronbach’s alpha coefficient for the scale was .896. The CFA indicated that the model fit indices were $\chi^2/df = 1.23$, CFI = .99, IFI = .99, NFI = .94, and RMSEA = .02. These findings indicated that the measurement model fitted the data well. The regression coefficients for the subdimensions are presented in Figure 7.



the measures. However, Harman's single-factor test has limited sensitivity and cannot rule out common method variance. Moreover, because the constructs were assessed using self-report instruments administered to the same participants during the same data-collection period, some degree of common method variance may remain. Accordingly, the Harman test is interpreted here as a preliminary diagnostic rather than definitive evidence of the absence of common method bias.

Table 2
Normality Test Results for the Measurement Instruments

Variables	N	M	SD	Skewness	Kurtosis
SCQ	482	3.15	0.55	0.114	-0.363
Knowledge	482	3.32	0.69	-0.052	-0.469
Social	482	3.15	0.81	0.000	-0.561
Economic	482	3.34	0.87	-0.156	-0.672
Environment	482	3.47	0.82	-0.289	-0.518
Attitude	482	3.02	0.73	0.106	-0.572
Social	482	3.05	0.86	-0.003	-0.745
Economic	482	2.85	0.89	0.167	-0.618
Environment	482	3.17	0.89	-0.102	-0.620
Behaviour	482	3.10	0.74	0.011	-0.701
Social	482	3.16	0.87	-0.120	-0.674
Economic	482	2.89	0.92	0.159	-0.765
Environment	482	3.26	0.84	-0.135	-0.512
EASLRAS	482	2.87	0.67	-0.062	-0.566
CDSK	482	2.97	0.77	0.014	-0.551
IRP	482	3.06	0.83	-0.167	-0.560
AV	482	2.78	0.82	0.028	-0.572
PCBI	482	2.65	0.82	0.199	-0.424
GCCAS	482	2.92	0.70	0.071	-0.550
ENHE	482	2.99	0.82	0.042	-0.514
ECR	482	3.05	0.96	-0.081	-0.655
AGOA	482	2.68	0.83	0.254	-0.436
RE	482	2.93	0.91	-0.078	-0.746

Skewness values ranged from -0.289 to 0.254, and kurtosis values ranged from -0.765 to -0.363 (Table 2). In the literature, it is generally suggested that skewness and kurtosis coefficients within the ± 3 interval are acceptable for meeting the normality assumption (Buyukozturk et al., 2016; Kalayci, 2017; Kline, 2023). The skewness and kurtosis values reported in Table 2 did not suggest substantial departures from univariate normality. In the study, partial correlation coefficients were computed to assess the assumption of multicollinearity. Correlations among the total scale scores are presented in Table 3.

Table 3
Findings from the Correlation Analysis

Variables	SCQ	EASLRAS	GCCAS
SCQ	1		
EASLRAS	.387**	1	
GCCAS	.484**	.411**	1

** $p < .01$

In the literature, it is emphasised that, when assessing the multicollinearity assumption, correlation coefficients between variables should not be excessively high; values such as .85 (Kline, 2023) or .90 (Tabachnick & Fidell, 2012) are commonly used as threshold criteria. In the present study, the highest correlation was observed between SCQ and GCCAS ($r = .484, p < .01$), whereas the lowest correlation was observed between SCQ and EASLRAS ($r = .387, p < .01$). These correlations did not suggest substantial overlap among the three scale scores. The extent to which a linear function can adequately represent the relationships among variables is referred to as linearity (Tabachnick & Fidell, 2012). The correlation coefficients obtained in this study suggest that the linearity assumption is also satisfied.

Multi-group confirmatory factor analysis (MG-CFA) was used to assess measurement invariance across science and mathematics teachers. This approach allows measurement models to be examined simultaneously across groups (Brown, 2015; Harrington, 2009). In the present study, MG-CFA assessed whether the constructs were measured comparably across the two groups. In this approach, measurement invariance across groups was evaluated by imposing constraints on key parameters of the measurement model, such as factor loadings and item intercepts. These constraints enable meaningful comparisons of factor structure and item functioning across groups and allow simultaneous assessment of overall model fit using data from multiple groups. The measurement invariance literature has recommended a sequential procedure that begins with the least restrictive model (configural invariance) and proceeds to more restrictive levels, including metric and scalar invariance. Model fit was assessed using χ^2 , χ^2/df , CFI, TLI, IFI, and RMSEA. At each stage of measurement invariance testing, changes in CFI (ΔCFI) were examined relative to the preceding model. Differences in CFI and TLI within $\pm .01$ are generally interpreted as evidence that the more constrained model remains acceptable, and that measurement invariance is supported (Chen et al., 2008; Cheung & Rensvold, 2002). Based on these criteria, measurement invariance was tested across science and mathematics teachers at the configural, metric, scalar, and strict levels. The models estimated in this process, along with the parameters constrained and tested for equality at each level, are presented in Table 4.

Table 4
Equality Constraints Across Measurement Invariance Models

Invariance Model	Additional Constraint at This Stage	Cumulative Equality Constraints Across Groups
Configural	Same factor structure across groups	No equality constraints beyond those required for model identification
Metric	Factor loadings constrained to equality	Equal factor loadings
Scalar	Indicator intercepts constrained to equality	Equal factor loadings and indicator intercepts
Strict	Indicator residual variances constrained to equality	Equal factor loadings, indicator intercepts, and indicator residual variances

Research Results

Descriptive statistics were calculated for the scale and subscale scores, including means, standard deviations, and observed minimum and maximum values. For descriptive interpretation, the possible response range of 1–5 was divided into three equal-width intervals, calculated as $(5-1)/3$. Mean scores rounded to two decimal places

were classified as low (1.00–2.33), moderate (2.34–3.67), or high (3.68–5.00). These categories served as descriptive labels rather than validated thresholds of awareness or competence. Table 5 presents the results.

Table 5
Descriptive Results for Scale and Subscale Scores

Scale or Subscale	Min	Max	<i>M</i>	<i>SD</i>
SCQ total	1.66	4.57	3.15	0.55
Knowledge	1.58	4.93	3.32	0.69
Attitude	1.33	5.00	3.02	0.73
Behaviour	1.28	4.86	3.10	0.74
EASLRAS total	1.22	4.48	2.87	0.67
CDSK	1.25	4.83	2.97	0.77
IRP	1.00	5.00	3.06	0.83
AV	1.00	4.75	2.78	0.82
PCBI	1.00	4.88	2.65	0.82
GCCAS total	1.21	4.77	2.92	0.70
ENHE	1.00	5.00	2.99	0.82
ECR	1.00	5.00	3.05	0.96
AGOA	1.00	5.00	2.68	0.83
RE	1.00	5.00	2.93	0.91

Note. *N* = 482 for all scores.

As shown in Table 5, all scale and subscale means fell within the moderate descriptive category. The mean SCQ total score was 3.15 (*SD* = 0.55). Among its three subscales, Knowledge had the highest mean (*M* = 3.32), followed by Behaviour (*M* = 3.10) and Attitude (*M* = 3.02). The mean EASLRAS total score was 2.87 (*SD* = 0.67), with subscale means ranging from 2.65 for PCBI to 3.06 for IRP. The mean GCCAS total score was 2.92 (*SD* = 0.70), with subscale means ranging from 2.68 for AGOA to 3.05 for ECR. These differences describe the observed mean scores and do not establish statistically significant differences between subscales. Table 6 presents the comparisons between science and mathematics teachers.

Table 6
Scale and Subscale Scores by Teaching Disciplines

Scale or Subscale	Science Teachers, <i>M</i> (<i>SD</i>)	Mathematics Teachers, <i>M</i> (<i>SD</i>)	<i>t</i>	<i>p</i>
SCQ total	3.21 (0.56)	3.08 (0.53)	2.565	.011
Knowledge	3.37 (0.68)	3.25 (0.70)	1.859	.064
Attitude	3.09 (0.74)	2.94 (0.71)	2.334	.020
Behaviour	3.15 (0.73)	3.04 (0.76)	1.704	.089
EASLRAS total	2.93 (0.67)	2.78 (0.66)	2.485	.013
CDSK	3.06 (0.77)	2.86 (0.76)	2.833	.005
IRP	3.13 (0.81)	2.97 (0.86)	2.114	.035
AV	2.82 (0.85)	2.72 (0.79)	1.327	.185
PCBI	2.72 (0.82)	2.57 (0.80)	2.004	.046

Scale or Subscale	Science Teachers, <i>M</i> (<i>SD</i>)	Mathematics Teachers, <i>M</i> (<i>SD</i>)	<i>t</i>	<i>p</i>
GCCAS total	2.94 (0.72)	2.89 (0.68)	0.777	.437
ENHE	3.03 (0.84)	2.94 (0.81)	1.232	.219
ECR	3.04 (0.98)	3.07 (0.93)	–0.412	.681
AGOA	2.71 (0.85)	2.65 (0.80)	0.774	.439
RE	2.97 (0.95)	2.88 (0.86)	1.010	.313

Note. Science teachers: *N* = 269; mathematics teachers: *N* = 213.

Table 6 shows that science teachers scored significantly higher than mathematics teachers on the SCQ total score ($p = .011$) and the Attitude subscale ($p = .020$). The differences in Knowledge and Behaviour scores were not statistically significant. Science teachers also scored significantly higher on the EASLRAS total score ($p = .013$) and the CDSK ($p = .005$), IRP ($p = .035$), and PCBI ($p = .046$) subscales, whereas the difference in AV was not significant. No statistically significant differences were found for the GCCAS total score or its subscales. These comparisons were evaluated at the nominal .05 level. The correlations among the study variables are presented in Table 7.

Table 7
Correlation Coefficients among the Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.SCQ	1													
2.K	.761*	1												
3.A	.772*	.399*	1											
4.B	.770*	.380*	.376*	1										
5.EASLRAS	.387*	.363*	.250*	.283*	1									
6.CDSK	.365*	.347*	.227*	.270*	.819*	1								
7.IRP	.293*	.281*	.187*	.209*	.826*	.572*	1							
8.AV	.323*	.297*	.216*	.235*	.829*	.565*	.571*	1						
9.PCBI	.306*	.282*	.199*	.225*	.842*	.597*	.585*	.607*	1					
10.GCCAS	.484*	.399*	.346*	.371*	.411*	.331*	.359*	.343*	.329*	1				
11.ENHE	.401*	.324*	.293*	.309*	.346*	.263*	.291*	.294*	.296*	.815*	1			
12.ECR	.356*	.290*	.262*	.269*	.321*	.227*	.298*	.274*	.263*	.796*	.514*	1		
13.AGOA	.419*	.341*	.305*	.320*	.326*	.273*	.258*	.293*	.258*	.810*	.607*	.531*	1	
14.RE	.373*	.322*	.249*	.290*	.319*	.296*	.295*	.236*	.234*	.772*	.516*	.453*	.478*	1

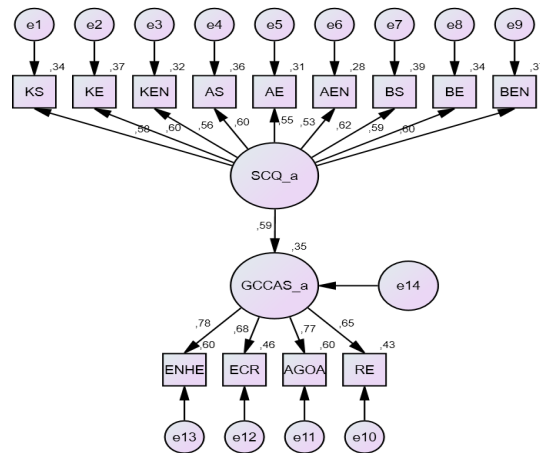
Note: K = Knowledge, A = Attitude, B = Behaviour, * $p < .05$

Table 7 presents the correlations among the scale and subscale scores. The coefficients ranged from .187 to .842. The highest correlation was between PCBI and the overall EASLRAS score ($r = .842$, $p < .05$). The lowest was between the SCQ Attitude subscale and the EASLRAS IRP subscale ($r = .187$, $p < .05$).

Results of the Measurement Model Testing

SCQ → GCCAS direct effects (H1)

To examine the effect of teachers' sustainability consciousness on climate change awareness, a direct path from the independent variable SCQ to the dependent variable GCCAS was specified in the structural model presented in Figure 8.

Figure 8*Structural Model for the Effect of Sustainability Consciousness on Climate Change Awareness*

The analysis revealed that sustainability consciousness positively and significantly predicted global climate change awareness ($\beta = 0.59$, $t = 8.30$, $p < .001$). In addition, the model accounted for 35% of the total variance in climate change awareness ($R^2 = .35$).

SCQ-GCCAS Measurement Invariance across Disciplines (H1a)

To test H1a, an MG-CFA was conducted across science and mathematics teachers, with group-specific model fit indices presented in Table 8.

Table 8*Model Fit Indices for the Measurement Model by Subject-Area Group*

Discipline	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI
Science	266.42	64	4.16	.011	.94	.94	.90
Mathematics	281.65	64	4.40	.014	.90	.91	.94

An examination of the goodness-of-fit results reported in Table 8 indicates that the following values were obtained for the science and mathematics teacher groups, respectively: $\chi^2/df = 4.16$ and 4.40; RMSEA = .011 and .014; CFI = .94 and .90; IFI = .94 and .91; and TLI = .90 and .94. The fit indices were generally consistent with the recommended criteria, indicating adequate model fit for both science and mathematics teachers. Measurement invariance of the SCQ-GCCAS model was subsequently assessed using MG-CFA. Table 9 presents the fit indices for the progressively constrained models.

Table 9*Fit Indices for Measurement Invariance Models across Subject-Area Groups*

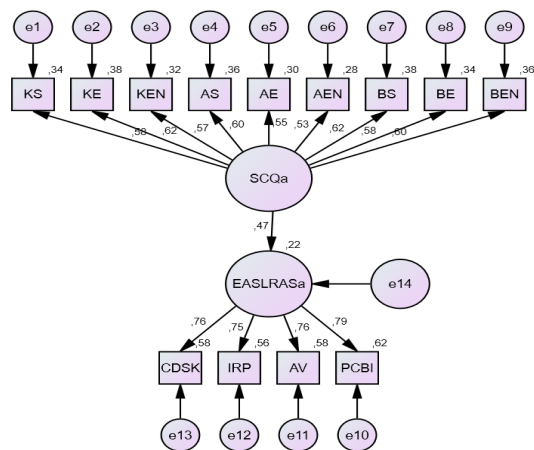
Invariance Stages	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI	ΔCFI
Configural	611.94	128	4.78	.009	.98	.98	.93	-
Metric	617.01	139	4.44	.008	.98	.98	.95	.00
Scalar	629.85	152	4.14	.008	.98	.98	.97	.00
Strict	653.70	168	3.89	.008	.98	.98	.99	.00

As shown in Table 9, measurement invariance was tested sequentially at the configural, metric, scalar, and strict levels using MG-CFA. The configural model yielded $\chi^2 = 611.94$, $df = 128$, $\chi^2/df = 4.78$, RMSEA = .009, CFI = .98, IFI = .98, and TLI = .93. When factor loadings were constrained (metric model), the fit indices were $\chi^2 = 617.01$, $df = 139$, $\chi^2/df = 4.44$, RMSEA = .008, CFI = .98, IFI = .98, TLI = .95, with $\Delta CFI = .00$. With intercepts additionally constrained (scalar model), the results were $\chi^2 = 629.85$, $df = 152$, $\chi^2/df = 4.14$, RMSEA = .008, CFI = .98, IFI = .98, TLI = .97, and $\Delta CFI = .00$. Finally, constraining residual variances (strict model) produced $\chi^2 = 653.70$, $df = 168$, $\chi^2/df = 3.89$, RMSEA = .008, CFI = .98, IFI = .98, TLI = .99, and $\Delta CFI = .00$. As reported in the table, CFI values remained unchanged to the reported precision across the configural, metric, scalar, and strict models.

SCQ → EASLRAS Direct Effects (H2)

To examine the effect of teachers’ sustainability consciousness on agricultural awareness, a direct path from the independent variable SCQ to the dependent variable EASLRAS was specified in the structural model presented in Figure 9.

Figure 9
Structural Model for the Effect of Sustainability Consciousness on Agricultural Awareness



In the model presented in Figure 9, the standardised path coefficient from sustainability consciousness to agricultural awareness was .47, and the model accounted for 22% of the variance in agricultural awareness.

SCQ-EASLRAS Measurement Invariance across Disciplines (H2a)

To test H2a, MG-CFA was conducted across science and mathematics teachers; Table 10 presents the group-specific fit indices.

Table 10
Model Fit Indices for the Measurement Model by Subject-Area Group

Discipline	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI
Science	277.92	64	4.34	.011	.94	.94	.90
Mathematics	296.32	64	4.63	.015	.90	.91	.90

An examination of the goodness-of-fit results reported in Table 10 indicates that the following values were obtained for the science and mathematics teacher groups, respectively: $\chi^2/df = 4.34$ and 4.63; RMSEA = .011 and .015; CFI = .94 and .90; IFI = .94 and .91; and TLI = .90. The reported indices generally indicated an acceptable fit of the measurement model in both groups. Measurement invariance of the SCQ-EASLRAS model was subsequently assessed using MG-CFA. Table 11 presents the fit indices for the progressively constrained models.

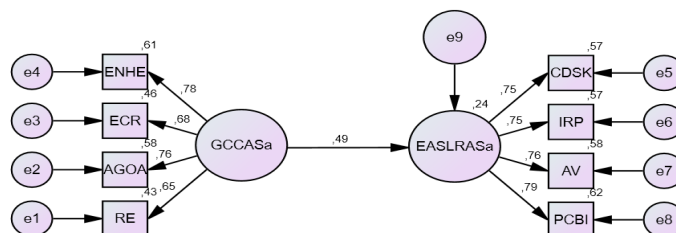
Table 11*Fit Indices for Measurement Invariance Models across Subject-Area Groups*

Invariance Stages	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI	ΔCFI
Configural	638.61	128	4.99	.080	.98	.98	.93	-
Metric	645.59	139	4.64	.080	.98	.98	.95	.00
Scalar	660.81	152	4.35	.080	.98	.98	.97	.00
Strict	675.65	168	4.02	.070	.98	.98	.99	.00

As shown in Table 11, measurement invariance was tested sequentially at the configural, metric, scalar, and strict levels using MG-CFA. The configural model yielded $\chi^2 = 638.61$, $df = 128$, $\chi^2/df = 4.99$, RMSEA = .08, CFI = .98, IFI = .98, and TLI = .93. When factor loadings were constrained (metric model), the fit indices were $\chi^2 = 645.59$, $df = 139$, $\chi^2/df = 4.64$, RMSEA = .08, CFI = .98, IFI = .98, TLI = .95, with $\Delta CFI = .00$. With intercepts additionally constrained (scalar model), the results were $\chi^2 = 660.81$, $df = 152$, $\chi^2/df = 4.35$, RMSEA = .08, CFI = .98, IFI = .98, TLI = .97, and $\Delta CFI = .00$. Finally, constraining residual variances (strict model) produced $\chi^2 = 675.65$, $df = 168$, $\chi^2/df = 4.02$, RMSEA = .07, CFI = .98, IFI = .98, TLI = .99, and $\Delta CFI = .00$. As reported in the table, CFI values remained unchanged to the reported precision across the configural, metric, scalar, and strict models.

GCCAS → *EASLRAS* direct effects (*H3*)

To assess the effect of teachers' climate change awareness on their agricultural awareness, a direct path from GCCAS to EASLRAS was specified in the structural model (Figure 10).

Figure 10*Structural Model for the Effect of Climate Change Awareness on Agricultural Awareness*

The analysis revealed that climate change awareness positively and significantly predicted agricultural awareness ($\beta = 0.49$, $t = 8.07$, $p < .001$). In addition, the model accounted for 24% of the total variance in agricultural awareness ($R^2 = .24$).

GCCAS-EASLRAS measurement invariance across disciplines (H3a)

To test H3a, an MG-CFA was conducted across science and mathematics teachers, with group-specific model fit indices presented in Table 12.

Table 12*Model Fit Indices for the Measurement Model by Subject-Area Group*

Discipline	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI
Science	15.02	19	0.79	.00	1.00	1.00	1.00
Mathematics	18.46	28	0.66	.00	1.00	1.00	1.00

An examination of the goodness-of-fit results reported in Table 12 indicates that the following values were obtained for the science and mathematics teacher groups, respectively: $\chi^2 = 15.02$ and 18.46 ; $df = 19$ and 28 ; $\chi^2/df = 0.79$ and 0.66 ; RMSEA = .00; CFI = 1.00; IFI = 1.00; and TLI = 1.00. The fit indices were consistent with the recommended criteria for good fit, indicating that the measurement model fitted the data well for both science and mathematics teachers. Measurement invariance of the GCCAS–EASLRAS model was subsequently assessed using MG-CFA. Table 13 presents the fit indices for the progressively constrained models.

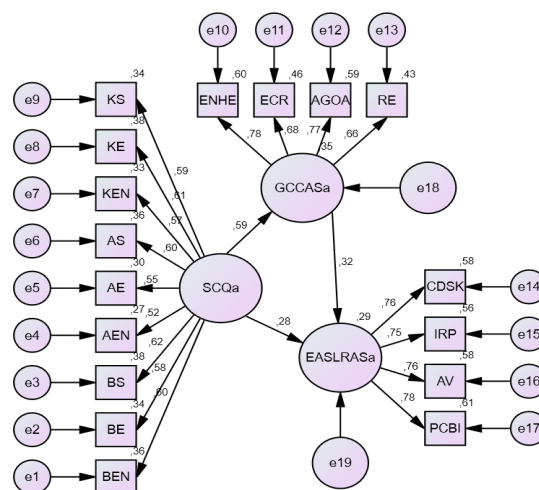
Table 13*Fit Indices for Measurement Invariance Models across Subject-Area Groups*

Invariance Stages	χ^2	df	χ^2/df	RMSEA	CFI	IFI	TLI	ΔCFI
Configural	33.48	38	0.88	.00	1.00	1.00	1.00	-
Metric	42.49	44	0.97	.00	1.00	1.00	1.00	.00
Scalar	54.55	52	1.05	.01	1.00	1.00	1.00	.00
Strict	64.88	63	1.03	.01	1.00	1.00	1.00	.00

As shown in Table 13, measurement invariance was tested sequentially at the configural, metric, scalar, and strict levels using MG-CFA. The configural model yielded $\chi^2 = 33.48$, $df = 38$, $\chi^2/df = 0.88$, RMSEA = .00, CFI = 1.00, IFI = 1.00, and TLI = 1.00. When factor loadings were constrained (metric model), the fit indices were $\chi^2 = 42.49$, $df = 44$, $\chi^2/df = 0.97$, RMSEA = .00, CFI = 1.00, IFI = 1.00, and TLI = 1.00, with $\Delta CFI = .00$. With intercepts additionally constrained (scalar model), the results were $\chi^2 = 54.55$, $df = 52$, $\chi^2/df = 1.05$, RMSEA = .00, CFI = 1.00, IFI = 1.00, and TLI = 1.00, and $\Delta CFI = .00$. Finally, constraining residual variances (strict model) produced $\chi^2 = 64.88$, $df = 63$, $\chi^2/df = 1.03$, RMSEA = .01, CFI = 1.00, IFI = 1.00, and TLI = 1.00 and $\Delta CFI = .00$. As reported in the table, CFI values remained unchanged to the reported precision across the configural, metric, scalar, and strict models.

Climate Change Awareness as Mediator: Testing H4

To test whether climate change awareness mediated the relationship between sustainability consciousness and agricultural awareness, the model shown in Figure 11 was specified and estimated.

Figure 11*Mediation Model of Sustainability Consciousness, Climate Change Awareness, and Agricultural Awareness*

The results indicated that sustainability consciousness positively and significantly predicted climate change awareness ($\beta = 0.59$, C.R. = 9.04, $p < .001$). Climate change awareness also had a positive and statistically significant

effect on agricultural awareness ($\beta = 0.32$, C.R. = 4.76, $p < .001$). In addition, the direct effect of sustainability consciousness on agricultural awareness remained statistically significant ($\beta = 0.28$, C.R. = 4.00, $p < .001$). The model explained 29% of the variance in agricultural awareness ($R^2 = .29$). The standardised indirect effect was $\beta = 0.19$, whereas the standardised total effect was $\beta = 0.47$. The ratio of the indirect effect to the total effect indicated that climate change awareness accounted for approximately 40.4% of the total effect of sustainability consciousness on agricultural awareness. The estimated direct and indirect effects were positive, consistent with the hypothesised mediation model.

Discussion

This study examined the relationships among STEM educators' sustainability consciousness, climate change awareness, and agricultural awareness. Findings from the descriptive analyses indicated that STEM educators' levels of sustainability consciousness, climate change awareness, and agricultural awareness generally clustered at a "moderate" level. This "moderate" tendency suggested that educators were neither entirely uninformed nor fully competent regarding these critical issues; rather, although they possessed a degree of theoretical familiarity, they experienced uncertainty about deeply internalising the subject matter and translating it into action. This finding is strongly consistent with Dorji et al. (2021), who have reported "moderate" levels of climate change awareness among teachers and have noted that teachers tend to focus on impacts rather than underlying causes, as well as with Debrah et al. (2021), who have found that teachers' knowledge and practices regarding waste management in developing countries remained at a "moderate" level. Furthermore, studies have indicated that pre-service teachers often demonstrate only a moderate level of understanding of sustainable development concepts and lack sufficient conceptual depth, which supports the interpretation that participants remained at a "moderate" rather than a "high" level due to conceptual ambiguities (Gunduz et al., 2024).

Participants' mean Knowledge score was higher than their mean Behaviour score. This descriptive difference does not establish a discrepancy between knowledge and observed classroom practice. Venghaus et al. (2022) have highlighted differences between climate awareness and behavioural change, while Richter-Beuschel and Bögeholz (2020) have distinguished conceptual from procedural knowledge. These distinctions are relevant to interpreting self-reported scores, although the present study did not directly assess procedural knowledge or classroom teaching. Frameworks for sustainability competencies and reviews of teacher education have also addressed the broader preparation needed for sustainability education (Fischer et al., 2022; Wiek et al., 2011).

The disciplinary comparisons showed that science teachers scored higher on the SCQ total score and the Attitude subscale, whereas the differences in Knowledge and Behaviour were not statistically significant. Science teachers also scored higher on the EASLRAS total score and the CDSK, IRP, and PCBI subscales. No statistically significant differences were found for the GCCAS total score or its subscales. The observed score differences and the measurement invariance findings address distinct aspects of the comparison. Science and mathematics teachers may differ in their scores while the measurement models remain comparable across groups. These findings do not establish whether the structural relationships among the constructs are equal across disciplines. Wiek et al. (2011) have likewise argued that disciplinary background is a decisive factor in climate awareness, with environment- and science-based fields exhibiting higher levels of awareness. However, this pattern contradicts the earlier study by Akgul and Macaroglu (2011), which has suggested that prospective mathematics teachers' level of agricultural knowledge was higher than that of prospective science teachers. This discrepancy may stem from curricular revisions over the past decade, particularly under the STEM education approach, through which science curricula have been expanded to more extensively encompass sustainability and agriculture, or from structural differences in the pre-service teacher education received by the sampled groups. Overall, the descriptive findings indicated that, as Natalia et al. (2023) have noted, even when teachers demonstrate greater awareness than students, they may remain reluctant or insufficient in engaging in low-carbon behaviours and in translating this awareness into pedagogical practice.

The results of the SEM analyses confirmed that STEM educators' agricultural awareness was not an isolated cognitive construct; rather, it was the product of a hierarchical and interdependent mechanism shaped by overall sustainability consciousness and climate change awareness. Within the model, the strong predictive effect of sustainability consciousness on climate change awareness suggested that educators did not perceive the climate crisis as an independent environmental issue; instead, they framed it within a holistic perspective under the umbrella

of sustainable development, encompassing economic, social, and environmental dimensions. This finding is theoretically consistent with Mochizuki and Bryan (2015), who have argued that climate change education becomes more meaningful when integrated into the broader framework of Education for Sustainable Development, and with Dal et al. (2015), who have indicated that teachers' climate literacy is related to their general environmental consciousness. However, the present study went beyond this association by demonstrating that climate change awareness played a "partial mediating" role between overall sustainability consciousness and agricultural awareness. This structural relationship suggested that STEM educators not only linked agricultural processes directly to sustainability but also did so mainly through a "climate lens." In other words, for teachers, agriculture was both a victim of climate change (e.g., drought and yield loss) and a contributor to it (e.g., greenhouse gas emissions).

Although the proportions of variance explained by the model demonstrated that these domains were tightly interconnected within educators' cognitive structures, the magnitude of the unexplained variance and the low implementation scores (PCBI) observed in the descriptive statistics suggested that the model was strong in the "knowledge and awareness" dimension but remained limited in the "action and procedural knowledge" dimension. This pattern is consistent with the "attitude-behaviour gap" that Venghaus et al. (2022) have emphasised in their study in Germany, where behavioural outcomes remained weak despite high environmental awareness and positive attitudes. In our model, the translation of sustainability consciousness into agricultural awareness (the theoretical/"green" pathway) was statistically significant and positive; however, the extent to which this pathway was reflected in teachers' classroom practices and behavioural intentions (the practical/"brown" domain) was weak. This disconnect can be interpreted through the "types of knowledge" framework proposed by Richter-Beuschel and Bögeholz (2020): whereas our teachers' performance within the model rested on "situational" and "conceptual" knowledge, a lack of "procedural" (methodological) knowledge, required to translate knowledge into action and to address complex problems, prevented the structural model from generating robust behavioural outcomes.

The reported multi-group analyses addressed measurement invariance across science and mathematics teachers. Measurement invariance concerns the comparability of measurement models across groups and should be distinguished from equality of structural relationships (Brown, 2015; Harrington, 2009). Accordingly, these analyses do not establish whether sustainability consciousness, climate change awareness, and agricultural awareness were related to the same extent in both groups. This question requires a separate comparison of models with freely estimated and equality-constrained structural paths.

The "Brown in Practice" component of our findings was most sharply visible in the PCBI subscale of EASLRAS. This subscale measures not declarative knowledge about agriculture but teachers' pedagogical competence and behavioural intentions for classroom implementation. Its consistently low score across both disciplinary groups signalled that the structural model, though strong at the level of awareness, did not extend into instructional behaviour. This is precisely what the "Green in Theory, Brown in Practice" frame captures: the pathway from sustainability consciousness to agricultural awareness was robust, but the onward pathway from awareness to enacted teaching was broken. This pattern highlights the need for the model to incorporate not only cognitive awareness but also "emotional reflexivity," as West et al. (2020) have suggested, along with "procedural" interventions, such as the gamified STEM activities proposed by Ozdinc and Ceyhan (2024).

From a social-ecological systems perspective, teachers function as critical interface actors, agents positioned at the boundary between policy frameworks that demand sustainability integration and classroom ecologies in which students develop environmental cognitions (West et al., 2020). Social-ecological systems theory (Ostrom, 2009) conceptualises such interface actors as essential for translating systemic sustainability imperatives into local behavioural adaptations. The present findings suggested that this interface was cognitively robust but behaviourally porous: teachers possessed the mental maps to connect sustainability, climate, and agriculture as a system, but lacked the instructional routes to translate these maps into enacted teaching. This distinction between cognitive mapping and behavioural navigation mirrors Ostrom's broader argument that the mere understanding of social-ecological interdependencies does not automatically generate adaptive management capacity; the institutional scaffolding to act upon that understanding must be deliberately built. In educational systems, this scaffolding corresponds to ongoing professional development, mentoring structures, and curriculum frameworks that provide teachers with the procedural knowledge and contextual support needed to enact sustainability education, not merely to endorse it. The low PCBI scores observed in this study thus signalled not an individual deficit, but a systemic failure of the institutional environment to support the behavioural expression of teachers' existing cognitive resources.

A further consideration concerns the gender composition of the sample, in which male teachers constituted 65.1% of participants. A consistent finding in the sustainability education literature has been that female educators and students tend to exhibit higher levels of sustainability consciousness, particularly in the attitudinal and behavioural domains (Berglund et al., 2014; Olsson & Gericke, 2017). The overrepresentation of male teachers in the present sample may therefore have contributed to the moderate, rather than high, awareness levels observed descriptively. The extent to which the gender composition influenced the estimated relationships was not examined. Future research could assess gender-related differences using appropriately designed samples and analyses.

Conclusions and Implications

This study indicated that STEM educators' overall sustainability consciousness was a fundamental predictor of both climate change and agricultural awareness; however, it also revealed a systematic "implementation gap" in translating this awareness into pedagogical action. The findings suggested that teachers could conceptually connect climate- and agriculture-related issues at a theoretical level. Yet, they faced constraints in the procedural and instructional competencies required to transfer this knowledge into classroom practice. In this respect, the study offers an original contribution by empirically demonstrating that awareness alone does not automatically yield instructional transformation. The most critical practical implication is that teacher education programmes should move beyond merely increasing environmental knowledge and instead prioritise strengthening pedagogical content knowledge and classroom enactment skills, specifically, competence in teaching this knowledge effectively. At the same time, given the limitation that the data were based on self-reports, the results underscore the urgency of practice-oriented educational reforms to close the gap between pro-environmental discourse and enacted practice.

Several directions merit further research. First, the present study's cross-sectional design precluded causal inference; longitudinal designs that track changes in sustainability consciousness and its downstream effects on classroom practice would substantially strengthen the causal interpretation. Second, the eastern Turkish regional sample, though adequate for SEM, limited generalisability; multi-regional or cross-national replications would test the universality of the structural pathways identified here. A further limitation concerns the reliance on self-report measures administered concurrently to the same participants. Although Harman's single-factor test did not indicate a dominant single-factor structure, this procedure cannot definitively exclude common method variance. Future studies could reduce this risk by combining self-report measures with classroom observations, behavioural indicators, or temporally separated measurement occasions. Third, the "Brown in Practice" gap, low pedagogical competence despite moderate awareness, calls for qualitative research: in-depth interviews or classroom observations could illuminate the specific mechanisms through which teachers' cognitive maps fail to translate into instructional action. Finally, the mediating role of climate change awareness identified here should be tested with additional mediators, such as teachers' systems thinking competency or professional development exposure, to construct a more complete model of how sustainability consciousness is enacted in educational contexts.

From a sustainable development governance perspective, the findings carry direct implications for SDG Target 4.7, which calls for all learners to acquire the knowledge and skills needed to promote sustainable development by 2030, including through education for sustainable development and sustainable lifestyles. The systematic implementation gap documented here, moderate awareness paired with low pedagogical competence, suggested that SDG 4.7 cannot be achieved through awareness-raising initiatives alone. Rather, meeting this target requires institutionally supported, practice-based teacher education programmes that develop procedural and pedagogical content knowledge alongside declarative understanding. In the Turkish context specifically, where the newly adopted national curriculum framework references global sustainability goals but lacks detailed subject-specific guidance on climate-agriculture linkages, the present findings provide an empirical baseline against which future policy reforms can be assessed. Monitoring progress towards SDG 4.7 at the classroom level thus requires instruments that simultaneously capture what teachers know, how they feel about it, and, critically, whether and how they teach it. The EASLRAS instrument developed and applied in this study represents one such tool.

Declaration of Interest

The authors declare no competing interest.

Declaration of Generative AI and AI-assisted Technologies

During the preparation of this work, the authors used ChatGPT in order to help with translation. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix 1

Abbreviations

The following abbreviations are used in this manuscript:

A	Attitude
AGFI	Adjusted Goodness-of-Fit Index
AGOA	Awareness of Global Organisations and Agreements
AMOS	Analysis of Moment Structures
AV	Attitudes and Values
B	Behaviour
CDSK	Cognitive Domain and System Knowledge
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
DW	Durbin-Watson
EASLRAS	Educators' Awareness and Sensitivity Levels Regarding Agriculture Scale
ECR	The Relationship Between Causal Factors and Energy Consumption
EFA	Exploratory Factor Analysis
ENHE	Impacts On Natural and Human-Made Environments
GCCAS	Global Climate Change Awareness Scale
GFI	Goodness-of-Fit Index
IFI	Incremental Fit Index
IRP	Impact And Risk Perception
K	Knowledge
KMO	Kaiser-Meyer-Olkin
MG-CFA	Multi-Group Confirmatory Factor Analysis
NFI	Normed Fit Index
PCBI	Pedagogical Competence and Behavioural Intention
RE	Causal Factors
RMSEA	Root Mean Square Error of Approximation
SCQ	Sustainability Consciousness Questionnaire
SDG	Sustainable Development Goal
SEM	Structural Equation Modelling
SRMR	Standardised Root Mean Square Residual
STEM	Science, Technology, Engineering, and Mathematics
TLI	Tucker-Lewis Index



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