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Teacher Agency, Artificial Intelligence and Climate Literacy: Conceptual Background

Büşra Dursun[1]

[1] Independent Researcher, Bursa, Türkiye

Correspondence: Büşra Dursun, Independent Researcher, Bursa, Türkiye.

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Abstract

This study represents Phase-2 of the international "Teachers as Climate Leaders – Teacher-led Climate Culture Model (TCCM)" research and extends earlier work on teacher leadership and school sustainability culture by integrating Artificial Intelligence (AI) as a key dimension shaping educational practice (Holmes et al., 2019; UNESCO, 2023). The study examines relationships among teachers' use of AI, teacher agency, climate literacy, and digital equity within school contexts (Priestley et al., 2015; Warschauer & Matuchniak, 2010). Data were collected through international teacher and student surveys conducted across multiple countries, focusing on teachers' AI confidence, school culture, perceptions of equity, and students' climate understanding and engagement. Using a mixed-methods design, the study explores AI not merely as a technological tool but as a socio-educational factor influencing professional judgment, school climate, and students' capacity to critically understand and act on climate issues (Williamson & Eynon, 2020; Selwyn, 2022). The findings contribute to current debates on AI in education, strengthen climate literacy discourse, and inform policy discussions related to COP31 and global climate-education frameworks (UNFCCC, 2022; UNESCO, 2020). Quantitative results indicate that AI use is strongly associated with teacher agency (r = .657), which is in turn aligned with more positive school-climate perceptions and student climate-literacy outcomes.

Keywords: artificial intelligence, teacher agency, climate literacy, digital equity, sustainability education, school climate culture

1. Introduction

Climate change represents one of the most pressing global challenges of the twenty-first century, and education is increasingly recognised as a central arena for developing the knowledge, values, and competencies required to respond to it effectively (IPCC, 2023; UNESCO, 2020). Schools are not merely spaces where climate-related information is transmitted; they are also contexts in which identities, beliefs, and capacities for action are shaped. Within this framework, teachers play a pivotal role. Their professional judgment, leadership, confidence, and the cultures they help cultivate within schools significantly influence how students understand climate change, evaluate information, and develop a sense of agency regarding whether their actions can make a difference (Hargreaves & Fullan, 2012; Mogren et al., 2019). Consequently, teacher agency and school sustainability culture emerge as critical elements in strengthening meaningful and transformative climate education.

At the same time, the rapid development of Artificial Intelligence (AI) is reshaping educational environments. AI has emerged not merely as a technical innovation, but as a force capable of transforming teaching practices, curriculum experiences, and school dynamics (Holmes et al., 2019; Luckin et al., 2016). It holds the potential to support teachers through enhanced access to resources, personalisation, and increased efficiency; however, it also raises critical questions related to autonomy, ethics, equity, and professional identity (Selwyn, 2022; Eubanks, 2018). In the context of climate education, AI may create new opportunities for accessing data, simulations, and knowledge, while simultaneously introducing risks such as misinformation, over-reliance, or the widening of existing inequalities when access and literacy are uneven.

Phase-1 of the Teachers as Climate Leaders – Teacher-led Climate Culture Model (TCCM) study examined teacher leadership, student perspectives, and school sustainability culture across multiple countries, highlighting the importance of teacher agency, supportive institutional environments, and meaningful engagement in fostering climate-positive school cultures (Priestley et al., 2015; Sterling, 2010). Building on this foundation, Phase-2 extends the scope of the research by integrating Artificial Intelligence (AI) as a critical dimension shaping these

processes. Rather than treating climate literacy, teacher agency, and AI as separate domains, the present study conceptualises them as interconnected dynamics that influence how climate education is experienced and enacted within school contexts.

Therefore, this study seeks to explore how teachers' use of AI, their confidence in engaging with it, school culture, and issues of digital equity relate to climate literacy and learning experiences within school contexts. In doing so, the study aims to contribute to ongoing debates on AI in education, deepen understanding of climate literacy as it is enacted in real school settings, and provide empirical evidence to inform global educational discussions, including those connected to COP31 and broader international sustainability agendas.

Although climate education, teacher agency, and Artificial Intelligence (AI) in education have each received increasing scholarly attention, they are still largely examined as separate areas of inquiry (Zawacki-Richter et al., 2019; Stevenson et al., 2017). Existing research tends to approach AI primarily from a technological or pedagogical innovation perspective, while studies on climate literacy often focus on knowledge or attitudes without sufficiently addressing the institutional, cultural, and leadership dynamics that shape how climate learning is enacted in schools (Williamson & Eynon, 2020; UNESCO, 2023). Moreover, although teacher agency is widely recognised as central to meaningful climate education, limited empirical evidence exists on how this agency is simultaneously influenced by AI, school culture, and conditions of digital equity. This highlights the need for research that moves beyond single-dimension perspectives and examines AI not merely as a tool, but as a socio-educational force interacting with teacher leadership, climate literacy, and school sustainability cultures. The present study responds to this gap by investigating how teachers' AI practices, confidence, institutional environments, and equity considerations relate to climate literacy within real school contexts in an international sample.

1.1 Purpose of the Study

Building on the Phase-1 findings of the Teachers as Climate Leaders (TCCM) project, this study aims to examine how Artificial Intelligence (AI), teacher agency, climate literacy, and digital equity intersect within real school contexts. Specifically, the study seeks to understand how teachers' engagement with AI, their confidence and professional autonomy, and the cultural and institutional environments of schools relate to students' climate literacy experiences. In doing so, the study conceptualises AI not merely as a technological tool, but as a socio-educational factor that shapes pedagogical practices, school culture, and students' capacity to critically understand and act on climate issues.

1.2 Research Questions

Guided by this purpose, the study addresses the following research questions:

RQ1. How do teachers use AI in their professional practice, and how confident do they feel engaging with it?

RQ2. How does teacher agency relate to AI use, school culture and climate education practices?

RQ3. How do school culture and digital equity conditions shape teachers' and students' climate literacy experiences?

RQ4. In what ways do AI, teacher agency and school sustainability culture interact in shaping climate literacy in schools?

2. Conceptual Background

This section presents the conceptual background that frames the study. It first discusses teacher agency within AI-driven educational contexts, then outlines contemporary understandings of climate literacy in schools, and finally brings these strands together to explain why they need to be examined in relation to one another.

2.1 Teacher Agency in AI-Driven Education

Recent research increasingly emphasises that Artificial Intelligence (AI) in education is not merely a technological innovation, but a factor that reshapes teacher identity, decision-making power, and professional roles (Holmes et al., 2019; Selwyn, 2022). While AI integration may reduce teachers' workload, support personalisation, and enhance instructional capacity, it simultaneously introduces new tensions related to autonomy, authority, and pedagogical control. In this context, teacher agency emerges as a critical lens for understanding how AI is experienced and enacted in schools (Priestley et al., 2015; Vähäsantanen, 2015). Studies suggest that agency in AI-mediated environments is multi-dimensional, encompassing professional judgment, participation in institutional decision-making, and moral–ethical responsibility. At the same time, AI literacy is increasingly conceptualised as a mediating construct that enables teachers to engage with AI critically, ethically, and purposefully, thereby supporting rather than diminishing professional agency (UNESCO, 2023; OECD, 2021). This perspective highlights the need for research that examines the relationships among AI, teacher agency, climate

literacy, and school culture within real educational settings.

2.2 Climate Literacy in School Contexts

Climate literacy has increasingly been recognised as a core educational objective in response to the growing urgency of the climate crisis. Beyond the acquisition of scientific knowledge, climate literacy encompasses the ability to critically evaluate information, understand the socio-political dimensions of climate change, and develop a sense of responsibility and agency for informed action (Stevenson et al., 2017; UNESCO, 2020). In school contexts, climate literacy is shaped not only by curriculum content but also by pedagogical approaches, institutional cultures, and opportunities for student participation.

Research suggests that when climate education is embedded within supportive school environments that encourage inquiry, dialogue, and critical thinking, students are more likely to develop deeper understanding and sustained engagement with climate issues (Mogren et al., 2019; Sterling, 2010). Teachers play a central role in this process by mediating complex knowledge, framing climate change as a meaningful and actionable issue, and modelling critical engagement. As such, climate literacy emerges as a relational and context-dependent construct, influenced by teacher agency, school culture, and broader conditions of equity and access.

2.3 Linking Teacher Agency, AI and Climate Literacy

Digital equity has become a critical concern in contemporary education, particularly as digital technologies and Artificial Intelligence (AI) increasingly shape teaching and learning processes. Digital equity extends beyond access to devices and connectivity to include meaningful opportunities to develop digital skills, critical literacy, and the capacity to engage with technology in informed and ethical ways (Warschauer & Matuchniak, 2010; Eubanks, 2018). Within school contexts, inequities may emerge through differences in infrastructure, institutional support, teacher preparedness, and students' socio-economic backgrounds.

Research highlights that when digital tools are integrated without attention to equity, existing educational disparities may be reinforced or intensified (Selwyn, 2022; UNESCO, 2023). Conversely, schools that adopt equity-oriented approaches—such as supporting teacher professional development, fostering inclusive digital cultures, and critically reflecting on technology use—are better positioned to harness the potential of AI for meaningful learning. In the context of climate education, digital equity is particularly significant, as unequal access to digital resources and AI literacy may limit students' opportunities to engage with climate data, simulations, and participatory learning experiences. As such, digital equity functions as a contextual condition that shapes how AI, teacher agency, and climate literacy intersect within schools.

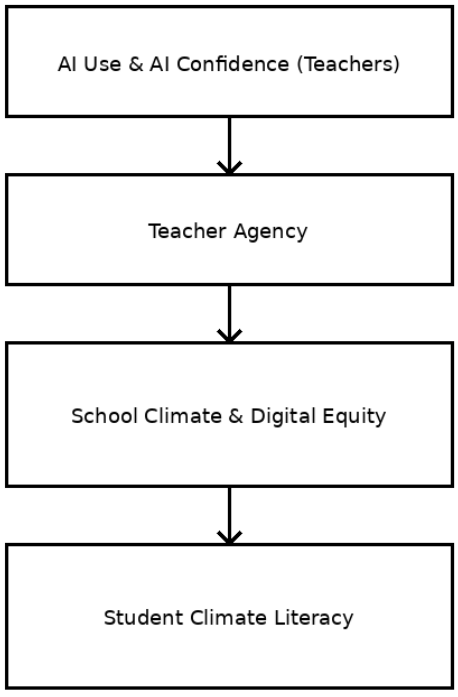

Figure 1. Conceptual model of AI use, teacher agency, school climate and student climate literacy

Figure 1 presents the conceptual framework guiding this study. Teachers' AI use and confidence are expected to influence teacher agency, which in turn shapes school climate and digital equity conditions, ultimately impacting student climate literacy.

3. Methodology

This study employed a mixed-methods research design to examine the relationships among Artificial Intelligence (AI), teacher agency, climate literacy, and digital equity within school contexts. A mixed-methods approach was selected to capture both quantitative patterns and qualitative insights, allowing for a more comprehensive understanding of how AI-supported practices are experienced by teachers and students across different educational settings. The research was conducted as part of Phase-2 of the Teachers as Climate Leaders – Teacher-led Climate Culture Model (TCCM) project and builds on the conceptual and empirical foundations established in Phase-1.

3.1 Research Design

The study adopted a sequential mixed-methods design, combining quantitative survey data with qualitative insights to explore the interactions among AI use, teacher agency, school culture, and climate literacy. Quantitative data were used to identify patterns and relationships across a multi-country sample, while qualitative data provided contextual depth and supported the interpretation of the statistical findings. This design enabled triangulation and strengthened the validity of the results by integrating multiple sources of evidence.

3.2 Participants and Sampling

The study involves international participants recruited through professional educational networks and voluntary participation invitations

- **Teacher participants** include educators from different countries, subject areas and levels of teaching experience.
- **Student participants** are those whose teachers voluntarily chose to share the student version of the survey in their classrooms.

Participation is voluntary, anonymous and based on convenience sampling with international reach.

Teacher Participants

A total of 48 teachers participated in Phase-2 of the study. Participants represented multiple countries, providing an international comparative dimension. The largest proportion of teachers were from Türkiye (n = 23), followed by India (n = 4), Nigeria (n = 2), Italy (n = 1), Pakistan (n = 1), Saudi Arabia (n = 1), Tanzania (n = 1), United States (n = 1), and additional single representations from Australia, Belgium, Ecuador, Ghana, Indonesia, Mozambique, Rwanda, Vietnam, Zimbabwe, and Azerbaijan. Teachers worked across primary, lower secondary, and upper secondary levels, representing diverse subject areas including Science/STEM, Humanities/Languages, Social Sciences, and cross-curricular coordination roles. This distribution confirms the international and cross-contextual scope of the teacher sample (see Figure 2).

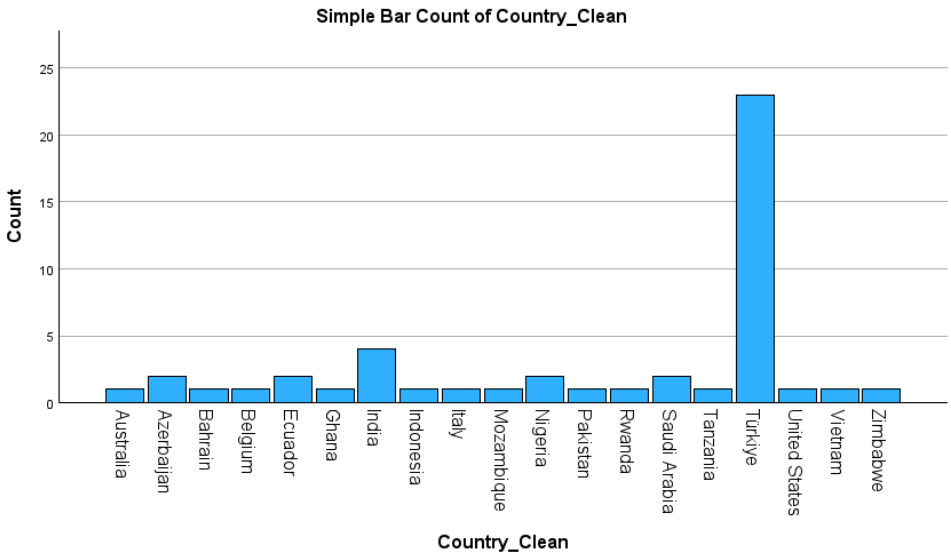

Figure 2. Country distribution of teacher participants (N = 48)

The teacher sample consisted of 48 participants from 15 countries, with Türkiye and India representing the largest groups.

Student Participants

A total of 112 students participated in Phase-2 of the study. Students were drawn primarily from secondary school levels, with age ranges predominantly between 14–18 years. The student sample was internationally distributed, with the largest group from Italy (n = 55), followed by Türkiye (n = 23) and the United States (n = 25). Additional representations came from countries including India, Pakistan, Nigeria, Malaysia, Saudi Arabia, Azerbaijan, England-UK, and one response categorized as unknown. The student sample therefore provides a meaningful international comparison across Southern European, Middle Eastern, and broader global educational contexts (see Figure 3).

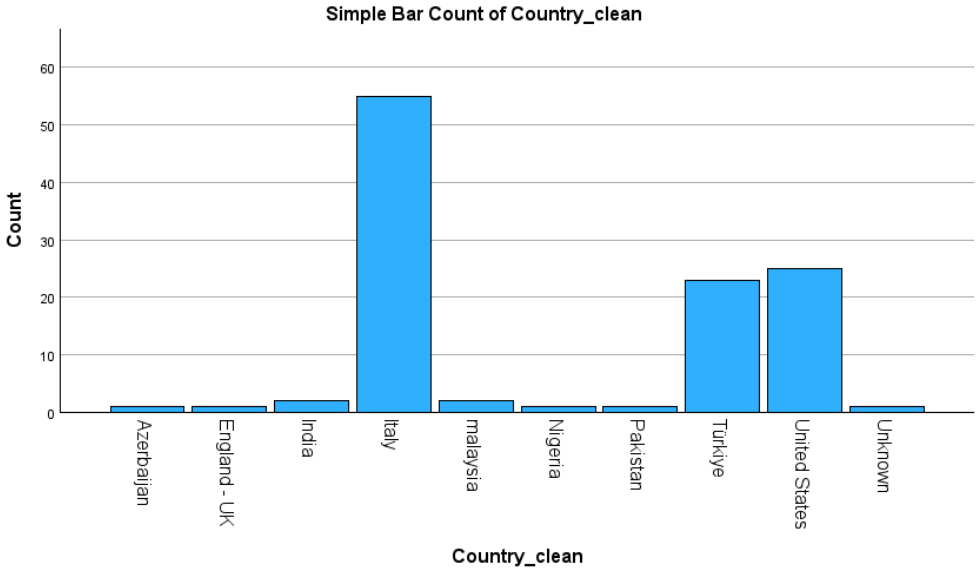

Figure 3. Student participants by country (N = 112)

The student sample consisted of 112 participants from 12 countries, with the largest groups from Italy, Türkiye, and the United States.

3.3 Data Collection Instruments

Data were collected through two online structured questionnaires:

- **Teacher Survey**, including:
  - demographic and background information
  - AI use and AI confidence
  - teacher agency
  - school culture and sustainability practices
  - perceptions of climate literacy
  - digital equity considerations
  - open-ended reflections on opportunities, risks and practice examples
- **Student Survey**, including:
  - age and country information
  - AI use in learning
  - confidence with climate information and data interpretation
  - perception of climate relevance and action
  - open-ended reflections on learning experiences

Both surveys were designed in English, ethically worded, and aligned with contemporary frameworks on AI in education, teacher agency and climate literacy.

3.4 Instruments / Measures

Data were collected using two structured online survey instruments developed for teachers and students. The teacher survey included Likert-scale items and open-ended questions designed to examine AI use in instructional practices, perceived teacher agency, school culture, and dimensions of digital equity. The student survey focused on climate literacy, engagement with climate-related learning activities, and perceptions of learning experiences related to sustainability education.

All Likert-scale items were measured using a five-point scale ranging from strongly disagree (1) to strongly agree (5). The instruments were developed in alignment with the conceptual framework of the Teachers as Climate Leaders – Teacher-led Climate Culture Model (TCCM) and refined based on insights from Phase-1 of the project. Prior to distribution, the survey items were reviewed to ensure clarity, relevance, and appropriateness across diverse educational and cultural contexts.

3.5 Ethical Considerations

Ethical considerations were carefully addressed throughout the research process. Participation in the study was entirely voluntary, and all participants were informed about the purpose of the research prior to data collection. Informed consent was obtained from all participants before they completed the surveys.

To ensure confidentiality and anonymity, no personally identifiable information was collected, and all responses were analysed in aggregated form. Participants were informed that they could withdraw from the study at any stage without any negative consequences. The study adhered to established ethical guidelines for educational research and was conducted in a manner that respected participants' rights, privacy, and well-being.

4. Findings

This section presents the findings of the study based on the analysis of quantitative and qualitative data collected from teachers and students across multiple countries. The results are organised around the key variables of the study, including AI use, teacher agency, climate literacy, school culture, and digital equity. Quantitative findings are reported first to outline general patterns and relationships among variables, followed by qualitative findings that provide contextual depth and illustrative insights into participants' experiences. Together, these findings address the research questions and offer a comprehensive understanding of how AI-supported teacher agency relates to climate literacy within school contexts.

4.1 Teacher Findings

4.1.1 Participant Profile

A total of 48 teachers participated in Phase-2 of the study. The sample represented 15 countries, with the largest proportion of participants from Türkiye (n = 23), followed by India (n = 4), Nigeria (n = 2), and single representations from Italy, Pakistan, Saudi Arabia, Tanzania, the United States, Australia, Belgium, Ecuador, Ghana, Indonesia, Mozambique, Rwanda, Vietnam, Zimbabwe, and Azerbaijan. Teachers worked across primary, lower secondary and upper secondary levels, covering diverse subject areas including Science/STEM, Humanities and Languages, Social Sciences, and cross-curricular coordination roles. This distribution reflects the international and cross-contextual nature of the teacher sample and provides a comparative perspective on AI use, teacher agency and climate literacy across different educational settings (see Figure 2).

4.1.2 Teacher Perceptions of AI, Agency & School Climate

Teachers' responses indicated generally positive perceptions of AI use in instructional practices, teacher agency, and aspects of school climate related to innovation and collaboration. Descriptive analyses showed that a majority of teachers reported moderate to high levels of confidence in integrating AI-supported tools into their teaching practices. Teachers also perceived AI as a supportive resource that could enhance instructional planning, differentiation, and student engagement.

In terms of teacher agency, participants reported a strong sense of professional autonomy and decision-making capacity, particularly in relation to adapting instructional strategies to address climate-related topics. Perceptions of school climate reflected supportive leadership, openness to pedagogical innovation, and collegial collaboration, although variations were observed across different national and institutional contexts.

Correlational analyses indicated positive relationships between perceived AI use and teacher agency, as well as between teacher agency and perceptions of a supportive school climate. These findings suggest that teachers who

reported higher engagement with AI-supported practices also tended to report stronger perceptions of agency and more favourable views of their school climate (see Table 1).

Table 1. Teacher scale descriptive statistics (N = 48)

Item	N	Min.	Max.	Mean	SD
@2IfeelconfidentusingAItoolsinmyprofessionalpract	48	1	5	4,166667	0,996448
@3AIhelpsmesavetimeonroutinetaskssoIcanfocusmo	48	1	5	4,208333	1,071057
@4IuseAItosupportordesignactivitiesrelatedtoclim	48	1	5	3,5	1,45865
@5Italkwithmystudentsaboutethicaluseandrisksof A	48	1	5	4,375	0,981206
IcanadaptAItoolstofitmyteachingstylemystudentsandm	48	2	5	4,208333	1,030561
UsingAIincreasesmyprofessionalcreativityasateacher	48	1	5	4,0625	1,13749
IfeelIhaveavoiceinhowAIisusedinmyschoolforexampl	48	1	5	3,5625	1,270052
Ifeeltrustedbymyschoolleadershiptomakedecisionsabout A	48	1	5	4,020833	1,157576
SometimesAImakesmefeellessincontroloftheteachingandl	48	1	5	3,0625	1,374637
IfeelconfidentcriticallyquestioningAIsuggestionsinsteado	48	1	5	4,354167	0,887012
AIsupportsmysenseofagencyasateacherIfeelmorecapable	48	1	5	3,916667	1,007067
Ifeelconfidentteachingclimatechangeandsustainabilityinm	48	1	5	4,333333	0,907025
Iusedatagraphsorvisualmaterialswhenteachingclimatean	48	1	5	4,104167	1,134368
AItoolshelpmeaccessusefulanduptodateinformationabout	48	1	5	3,958333	1,12908
AIsupportedexplanationsandresourceshelpmystudentsunderst	48	1	5	4	1,051847
Mystudentscanthinkcriticallyaboutthecausesandconsequenc	48	1	5	3,895833	1,015614
Mystudentsareabletoconnectclimatechangetotheirlocalco	48	1	5	3,979167	1,139047
IfeelconfidenthelpingstudentsevaluatewhetherAIgenerated	48	1	5	3,75	1,176001
Mostofmystudentshavereliableaccesstodigitaldevicesand	48	1	5	4,1875	1,044871
Thereareclearinequalitiesinaccesstotechnologyamongmyst	48	1	5	2,645833	1,630684
MyschoolconsidersdigitalequitywhenplanningtechnologyorA	48	1	5	3,583333	1,301935
AImaywidenexistinginequalitiesbetweenstudentsforexample	48	1	5	3,625	1,378019
ItrytodesignAIrelatedactivitiesthatdonotdisadvantages	48	1	5	3,8125	1,178825
InmyschoolethicalandsocialimplicationsofAIsuchasfai	48	1	5	3,5	1,237705
Studentvoiceislistenedtoandvaluedwhendecisionsaremade	48	1	5	3,5625	1,286695
Ourschoolsupportsstudentleadershipandagencyinclimateand	48	1	5	3,6875	1,431503
Doyouconsenttovoluntarilyparticipateinthisstudy = "Yes, I consent and would like to continue" (FILTER)	109	0	1	0,440367	0,498724
Valid N (listwise)	48				

4.1.3 Reliability of Scales

Reliability analysis indicated high internal consistency for the teacher instrument (Cronbach's $\alpha = .918$).

4.1.4 Key Relationships

Pearson correlation analyses (N = 48) indicated statistically significant positive relationships among teachers' AI engagement, teacher agency, and climate literacy indicators. AI use was strongly associated with teacher agency ($r = .657$, $p < .001$), suggesting that teachers who reported greater AI engagement also tended to perceive higher professional empowerment and agency. In addition, teacher agency showed a small-to-moderate positive association with climate literacy ($r = .296$, $p = .041$). AI use was also moderately correlated with climate literacy ($r = .458$, $p = .001$), indicating that greater engagement with AI-related practices aligned with higher confidence and capacity in climate education.

Table 2. Presents correlations among teacher AI use, agency, and climate literacy

Relationship	r	p
AI ↔ Teacher Agency	**.657**	**< .001**
Teacher Agency ↔ Climate Literacy	**.296**	**.041**
AI ↔ Climate Literacy	**.458**	**.001**

4.2 Student Findings

4.2.1 Participant Profile

A total of 112 students participated in Phase-2 of the study. Participants were predominantly drawn from secondary school levels, with most students aged between 14 and 18 years. The sample was internationally distributed, with the largest proportion from Italy (n = 55), followed by Türkiye (n = 23) and the United States (n = 25), alongside smaller representations from India, Pakistan, Nigeria, Malaysia, Saudi Arabia, Azerbaijan and England-UK. This international distribution provides a cross-contextual perspective on students' experiences of AI-supported learning and climate literacy across diverse educational settings (see Figures 4 and 5).

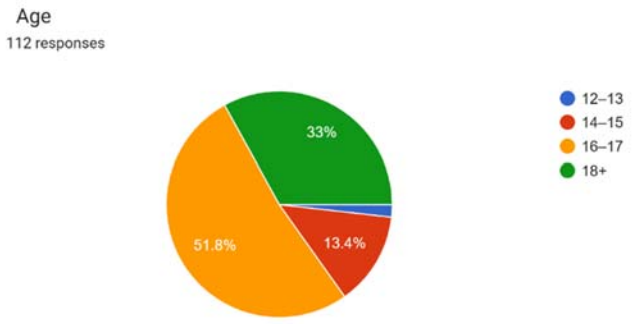

Figure 4. Student age distribution (N = 112)

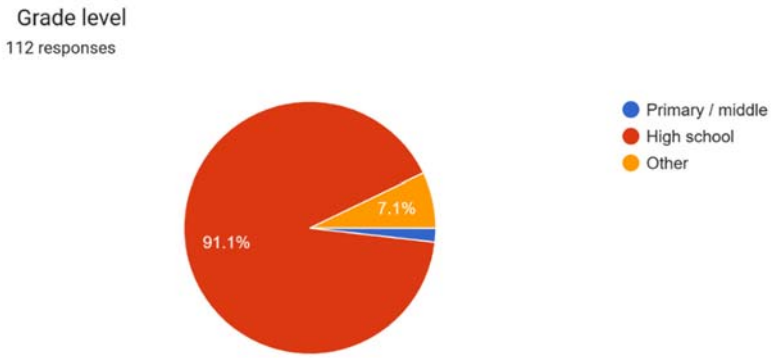

Figure 5. Student grade / school level distribution (N = 112)

4.2.2 AI in Learning, Climate Literacy & Green Skills

Descriptive statistics indicated generally positive student perceptions of AI-supported learning and climate literacy. Students reported moderate levels of engagement with AI tools in learning activities and perceived meaningful guidance from teachers regarding responsible and educational AI use. Climate literacy scores similarly reflected an overall awareness of climate change concepts and sustainability-oriented thinking. Detailed mean and standard deviation values for student-scale variables are presented in Table 3.

Table 3. Student scale descriptive statistics (N = 112)

Item	N	Min.	Max.	Mean	SD
@2AItoolshelpmeunderstanddifficulttopicsbetter	112	1	5	3,848214	1,108605
@3IfeelconfidentaskingquestionstoAItoolsandlearni	112	1	5	3,589286	1,135453
@4MyteachersexplainhowtouseAIsafelyandresponsibly	112	1	5	2,6875	1,388701
@5SometimesIworrythatAImayreplacesomepartsofwhat	112	1	5	3,258929	1,235697
@1Iunderstandthebasicideasofclimatechangeforexam	112	1	5	4,142857	0,918843
@2Ifeelconfidentreadingsimplegraphschartsormaps	112	2	5	3,8125	0,915642
@3Icanexplainhowclimatechangemayaffectmycountryo	112	1	5	3,607143	0,980505
@4Ifeelconfidentcheckingwhetherinformationaboutclim	112	2	5	3,526786	0,910003
@5IbelievewhatIdoindailylifecanhelptheenvironme	112	1	5	3,544643	1,10599

@1Ihaveheardaboutgreenskillsorjobsrelatedto	112	1	5	3,25	1,345664
@2Iwouldliketolearnmoreaboutgreenskillsandclimat	112	1	5	3,5625	1,168515
@3Myschoolsupportsstudentswhowanttotakeactionfor	112	1	5	3,285714	1,077439
@4IbelieveAIandtechnologycanhelpyoungpeoplecreate	112	1	5	3,508929	1,170166
Valid N (listwise)	112				

4.2.3 Reliability

Reliability analysis indicated acceptable internal consistency for the student instrument (Cronbach's $\alpha = .764$).

4.2.4 Key Relationships

Pearson correlation analyses in the student dataset (N = 112) revealed significant positive relationships among students' AI use, perceived teacher guidance on AI, and climate literacy. Students' AI use was positively associated with perceived teacher guidance on AI ($r = .284$, $p = .003$), indicating that students who engaged more frequently with AI tools also reported higher levels of teacher support in responsible and educational AI use. Perceived teacher guidance on AI showed a strong positive association with student climate literacy ($r = .603$, $p < .001$), suggesting that teacher facilitation of AI-supported learning environments aligns with higher student understanding of climate change concepts. AI use was also positively correlated with student climate literacy ($r = .213$, $p = .024$), indicating that AI-supported learning experiences may accompany increased student climate knowledge and awareness.

Table 4. Correlations among student AI use, perceived teacher guidance, and climate literacy (N = 112)

Relationship	**r**	**p**
AI use ↔ Student perceived teacher guidance on AI	.284	.003
Teacher guidance on AI ↔ Student Climate Literacy	.603	< .001
AI use ↔ Student Climate Literacy	.213	.024

4.3 Connecting Teachers and Students (Phase-2 Signature Section)

Cross-analysis of teacher and student findings reveals a coherent pattern linking AI engagement, teacher agency and climate literacy across both datasets. At the teacher level, higher AI use was associated with stronger professional agency and greater confidence in climate education practices. At the student level, perceived teacher guidance on AI showed a strong relationship with student climate literacy. Taken together, these findings suggest that when teachers feel empowered and competent in integrating AI into their professional practice, this agency translates into more effective AI-supported learning environments, which in turn align with higher levels of student climate literacy. This cross-level pattern provides quantitative support for the proposed Teacher-led Climate Culture Model (TCCM), highlighting teacher agency in AI-supported pedagogy as a key mechanism linking institutional innovation to student climate learning outcomes.

5. Discussion

5.1 What Do These Findings Tell Us About Teachers?

The findings indicate that AI engagement functions as a supportive mechanism for strengthening teacher agency, as reflected in the strong correlation between AI use and agency ($r = .657$, $p < .001$). Teachers who actively integrate AI tools into their professional practice reported higher levels of confidence, autonomy, and willingness to innovate in instructional design. In addition, positive perceptions of school climate appeared to reinforce this relationship, suggesting that institutional environments that encourage experimentation and digital innovation foster stronger professional agency.

From an equity perspective, AI-supported pedagogical practices also hold potential to reduce access gaps in climate education by enabling teachers to diversify learning resources and adapt instruction to varied student needs. Taken together, these results suggest that AI does not replace teacher professionalism but rather amplifies teachers' capacity to lead transformative learning processes.

5.2 What Do These Findings Tell Us About Students?

Student findings reveal that AI-supported learning environments are associated with higher levels of learner confidence and engagement. Students who experience guided and responsible AI use in classrooms tend to report stronger perceptions of teacher support, which in turn align with higher climate literacy. This suggests that climate

literacy is not merely the acquisition of factual knowledge but also involves developing self-efficacy and agency in addressing sustainability challenges. Furthermore, students' awareness of green skills and future-oriented competencies appears connected to exposure to AI-enhanced learning practices, indicating that digital tools may serve as catalysts for broader sustainability-oriented mindsets.

5.3 Linking Teachers and Students: The TCCM Logic Confirmed

When teacher and student findings were examined together, a coherent cross-level mechanism emerged. Phase-1 of the study proposed that teacher-led climate culture operates as a driving force in developing school-wide sustainability practices. Phase-2 extends this model by demonstrating that AI integration strengthens teacher agency, which subsequently translates into AI-supported instructional practices perceived by students.

This chain of influence aligns with the Teacher-led Climate Culture Model (TCCM), confirming that empowered teachers act as key mediators between institutional innovation and student climate learning outcomes. The results therefore support the proposition that teacher agency in AI-supported pedagogy constitutes a central mechanism in cultivating climate-conscious school cultures.

5.4 Contribution to Literature

This study contributes to the growing body of literature on AI in education by situating AI use within a teacher-centred and sustainability-oriented framework. While existing research has often focused on technological effectiveness or student outcomes in isolation, the present findings foreground teacher agency as a central mechanism through which AI-supported practices influence climate literacy in school contexts.

By integrating insights from a multi-country sample, the study extends current discussions on sustainability education beyond single-context analyses and highlights the importance of professional agency and school climate in shaping meaningful learning experiences. The findings also contribute to emerging debates on digital equity by illustrating how AI-supported pedagogical practices, when guided by teachers' professional judgement, may support more inclusive and adaptive approaches to climate education.

Taken together, the results advance understanding of how AI can function as an enabling condition—rather than a determining force—in teacher-led climate learning, offering a conceptual contribution to research on sustainability-focused pedagogy in diverse educational settings.

6. Policy & Practice Implications in the Context of COP31 and NDCs

6.1 Positioning the Findings Within the COP31 Agenda

The findings of this study demonstrate that Artificial Intelligence (AI) in education, teacher agency, supportive school climate, and digital equity collectively create a strong foundation for climate literacy development among students. In the context of COP31, where national commitments will increasingly require education systems to contribute to mitigation, adaptation and resilience outcomes, these results suggest that education should not remain a passive domain but become an active component of Nationally Determined Contributions (NDCs).

6.2 Integrating AI-Supported Climate Education into National Policies

Countries developing or revising their NDCs should incorporate education as a strategic pillar by:

- Embedding **AI-supported climate education** into national curricula
- Allocating resources for **teacher professional development in AI and climate pedagogy**
- Establishing **national guidelines** for ethical and pedagogically meaningful AI use in schools
- Ensuring climate education is designed not only as knowledge content, but as **applied competence development (data literacy, systems thinking, sustainability decision-making)**

This shifts education from awareness only → measurable climate competence.

6.3 Teacher Agency in Climate Education Policy

Findings indicate that teacher agency is a critical driver linking AI use to meaningful climate learning outcomes. Therefore:

- Teachers should be recognized within NDC frameworks not as implementers only, but as **climate education leaders**
- National policy should support:
    - school-level innovation autonomy
    - teacher-led program design

    - cross-national teacher collaboration networks (e.g., SDSN, UNESCO schools)
- Ministries of Education should institutionalize **"Teacher Agency Programs"** aligned to climate goals, supporting experimentation, reflection and localized adaptation rather than top-down compliance.

This reframes teachers as **policy actors** rather than passive recipients.

6.4 Ensuring Digital Equity as a Climate Equity Requirement

Digital inequity creates climate literacy inequity. If AI-supported learning becomes central to climate education, then:

- Ensuring equal access to AI tools, connectivity, and infrastructure must become part of climate justice measures
- NDCs should explicitly acknowledge **digital access for education** as a resilience factor
- Investments should prioritize:
    - under-resourced regions
    - low-income schools
    - rural and marginalized learners

Without this, AI-supported climate education risks reinforcing existing inequalities instead of reducing them.

6.5 Student Climate Literacy as a Measurable Outcome in NDC Monitoring

Countries should move beyond symbolic commitments and develop measurable education-linked indicators within NDC monitoring frameworks, such as:

- National climate literacy index benchmarks
- Student self-efficacy and agency indicators
- School-level climate action participation metrics
- Integration of climate learning outcomes into national reporting

This establishes education as an **evidence-based contributor** to national climate resilience rather than aspirational rhetoric.

6.6 From Policy to Action: A Practical Implementation Roadmap

Based on this study, a three-level implementation pathway is proposed:

School-Level

- AI-enabled climate learning platforms
- Teacher training on AI pedagogy & climate science
- Student-led climate inquiry, projects, and data interpretation

National-Level

- Integration of AI + climate literacy in curriculum & policy
- Funding mechanisms & digital infrastructure strategies
- Monitoring frameworks linked to NDC indicators

Global / COP31-Level

- Recognition of **education as a formal NDC pillar**
- International networks to support teacher agency globally
- Cross-country equity financing mechanisms for AI access in schools

6.7 Overall Policy Message

This study strongly suggests that AI, when combined with empowered teachers and equitable access, can significantly strengthen climate literacy. Therefore, as COP31 approaches, governments should position education not as a supportive side narrative but as a central strategic contributor in their Nationally Determined Contributions.

Education policy **is climate policy**.

7. Conclusion

This study examined how AI-supported pedagogical practices intersect with teacher agency, school climate, and climate literacy across diverse educational contexts. Drawing on multi-country data from teachers and students, the findings highlight the central role of teachers as mediators in translating digital tools into meaningful climate learning experiences.

The results suggest that AI, when embedded within supportive school environments and guided by teachers' professional judgement, may function as an enabling resource for strengthening agency and fostering climate literacy. Rather than positioning technology as a determining force, the study underscores the importance of teacher-led approaches in shaping sustainability-oriented learning cultures.

By integrating perspectives from multiple countries, the study contributes to ongoing discussions on sustainability education, digital equity, and the evolving role of educators in climate action. While the findings offer insights into AI-supported climate education, further research is needed to explore longitudinal impacts and contextual variations across education systems.

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Authors' contributions

Büşra Dursun was responsible for the study conception and design, data collection, data analysis, interpretation of findings, and manuscript preparation. The author read and approved the final manuscript.

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Competing interests

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Informed consent was obtained from all participants prior to participation. Participation was voluntary and anonymous.

Ethics approval

Not applicable. The study used voluntary, anonymous online surveys and did not collect personally identifiable information.

The study was conducted in accordance with ethical principles for educational research, including voluntary participation, informed consent, anonymity, and confidentiality.

Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

Data sharing statement

No additional data are available.

References

Anderson, A. (2012). Climate change education for mitigation and adaptation. *Journal of Education for Sustainable Development*, *6*(2), 191–206. https://doi.org/10.1177/0973408212475199

Eubanks, V. (2018). *Automating inequality: How high-tech tools profile, police, and punish the poor*. St. Martin's Press.

Hargreaves, A., & Fullan, M. (2012). *Professional capital: Transforming teaching in every school*. Routledge.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

ILO. (2015). *Guidelines for a just transition towards environmentally sustainable economies and societies for all*. International Labour Organization.

IPCC. (2023). *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report*. Intergovernmental Panel on Climate Change.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson.

Mogren, A., Gericke, N., & Scherp, H. Å. (2019). Whole-school approaches to education for sustainable development. *International Journal of Sustainability in Higher Education*, *20*(2), 272–288.

OECD. (2021). *AI in education: Challenges and opportunities*. OECD Publishing.

OECD. (2022). *Green skills for a sustainable economy*. OECD Publishing.

Priestley, M., Biesta, G., & Robinson, S. (2015). Teacher agency: What is it and why does it matter? In R. Kneyber & J. Evers (Eds.), *Flip the system: Changing education from the bottom up* (pp. 134–148). Routledge. https://doi.org/10.4324/9781315678573-15

Selwyn, N. (2022). *Should robots replace teachers? AI and the future of education*. Polity Press.

Sterling, S. (2010). Learning for resilience, or the resilient learner? Towards a necessary reconciliation in a paradigm of sustainable education. *Environmental Education Research*, *16*(5–6), 511–528. https://doi.org/10.1080/13504622.2010.505427

Stevenson, R. B., Nicholls, J., & Whitehouse, H. (2017). Transformative climate change education: Challenges for educators. *Environmental Education Research*, *23*(5), 687–699.

Tao, J., & Gao, X. (2017). Teacher agency and identity commitment in curricular reform. *Teaching and Teacher Education*, *63*, 346–355. https://doi.org/10.1016/j.tate.2017.01.010

UNESCO. (2020). *Education for sustainable development: A roadmap* (ESD for 2030). UNESCO Publishing.

UNESCO. (2023). *Guidance on generative AI in education and research*. UNESCO Publishing.

UNFCCC. (2022). *Action for climate empowerment (ACE) framework*. United Nations Framework Convention on Climate Change.

UNICEF. (2021). *Reimagining climate education and youth engagement*. UNICEF Office of Global Insight and Policy.

Vähäsantanen, K. (2015). Professional agency in the stream of change: Understanding educational change. *Teaching and Teacher Education*, *47*, 1–12. https://doi.org/10.1016/j.tate.2014.11.006

Warschauer, M., & Matuchniak, T. (2010). New technology and digital divides: From access to appropriation. *Review of Research in Education*, *34*, 179–225. https://doi.org/10.3102/0091732X09349791

Williamson, B., & Eynon, R. (2020). Historical threads of AI in education. *Learning, Media and Technology*, *45*(3), 223–235. https://doi.org/10.1080/17439884.2020.1798995

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, *16*(39). https://doi.org/10.1186/s41239-019-0171-0