

Article

Teaching Equity and Perceived Learning Effect in Dual-Teacher Classroom Under Education for Sustainable Development: A Comparative Study of Student Engagement Mechanisms Through the Opportunity-to-Learn Framework

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Abstract

Ensuring equitable access to quality education is essential for Education for Sustainable Development. However, the efficacy of innovative Education for Sustainable Development models like the Dual-Teacher Classroom in promoting teaching equity has not been sufficiently studied. Grounded in the Opportunity to Learn (OTL) theory—a theoretical framework that provides observational constructs for Education for Sustainable Development (ESD), which are operationalized as empirical measures in this study—this study investigates the mechanisms through which teaching equity influences perceived learning effect, with learning engagement as a mediator, among elementary students in Beijing, China. Data were collected from 278 participants using a validated questionnaire. The results reveal significant disparities between urban and rural students, with urban students demonstrating higher levels of teaching equity, learning engagement, and perceived learning effect. Mediation analysis indicated that learning engagement acts as a partial mediator for urban students, whereas it serves as a full mediator for rural students. These findings highlight the importance of context-sensitive instructional strategies to enhance equity and engagement in the Dual-Teacher Classroom. The study contributes to the discourse on educational sustainability by emphasizing the role of equitable teaching practices in fostering inclusive and effective learning environments. Practical implications for teacher collaboration and real-time feedback mechanisms are discussed.

Keywords: education for sustainable development (ESD); dual-teacher classroom; teaching equity; opportunity to learn (OTL); learning engagement; perceived learning effect



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1. Introduction

We are currently experiencing accelerated transformations in the global landscape and in the trajectory of human development, wherein sustainable development has emerged as an inevitable trend for societal progress and a critical pathway for addressing global challenges. Education serves as a pivotal bridge for achieving sustainability—it is both an integral component of Sustainable Development Goals (SDGs) and a fundamental mechanism to realize all SDG targets [1].

Following the United Nations' adoption of the 2030 Agenda for Sustainable Development in 2015, the global education community embraced the Education 2030 Framework for

Action. This framework established a worldwide consensus on Education for Sustainable Development (ESD), as outlined in SDG4, which defines ten specific targets [2]. Guided by this framework, China has actively implemented and promoted ESD initiatives, leading to the creation of a distinctive Dual-Teacher Classroom model that embodies innovative features of the sustainability pedagogy. This approach has emerged as an innovative teaching model that integrates local and remote instructors to bridge educational gaps between under-resourced and well-resourced schools, thereby laying a solid foundation for education in sustainable development. Typically, the Dual-Teacher Classroom involves an “input” group—often consisting of rural schools with limited resources—and an “output” group—usually urban schools with abundant educational advantages. This structure creates a natural setting for examining disparities in teaching equity and learning effects.

Despite extensive literature on teaching equity in conventional classrooms [3–7], research specifically targeting the unique mechanisms of teaching equity within the Dual-Teacher Classroom model for ESD remains limited. Moreover, recent scholarship calls for moving beyond technical or resource-based definitions of equity to focus on the relational and participatory dimensions of learning (Goldin et al., 2025; Freedman et al., 2025) [8,9]. Most existing studies have concentrated on resource allocation and learning performance in traditional settings, leaving unanswered how teaching equity practices influence student engagement and perceived learning effect in Dual-Teacher Classroom environments. Moreover, within the Dual-Teacher Classroom model, teaching equity serves as a key monitoring indicator for ESD [10]. Although the Opportunity to Learn (OTL) theory—a well-established representation of equity—has been applied in general educational contexts, its relevance and adaptation to ESD have not yet been thoroughly investigated.

To address this research gap, the study adopts the OTL framework to systematically examine the relationships among teaching equity, learning engagement, and perceived learning effect within the Dual-Teacher Classroom model for ESD. By comparing the experiences of students from both rural and urban groups, the research aims to elucidate the distinct pathways through which teaching equity influences perceived learning effect. Quantitative methods and structural equation modeling are employed to provide empirical evidence of these relationships, offering theoretical insights and practical recommendations for enhancing instructional practices in ESD.

This study contributes to the literature by empirically investigating the mediating role of learning engagement in Dual-Teacher Classrooms under the OTL framework, a novel approach that has not been thoroughly explored in previous research. Specifically, it addresses the gap in understanding how teaching equity practices influence perceived learning effect in the context of ESD, providing new insights for sustainable educational development.

1.1. Education for Sustainable Development

Education for Sustainable Development (ESD) has distinct phases. Based on the social contexts and primary issues addressed during different periods, it can broadly be divided into four stages: “education for environmental protection”, “environmental education for adapting to sustainable development”, “education for sustainable development aimed at building a fair and sustainable future”, and “education for sustainable development dedicated to realizing the coexistence of humans and the planet”.

Initially, the core focus of ESD was rooted in environmental protection. Through an emphasis on environmental education, it aimed to raise ecological awareness and foster public competence in addressing environmental issues. Entering the 20th century, environmental education evolved into “environmental education for adapting to sustainable development.” The 2002 World Summit on Sustainable Development gradually

contributed to a broadening international consensus around “education for sustainable development aimed at building a fair and sustainable future.” During the United Nations Decade of Education for Sustainable Development (2005–2014), the international community introduced core principles of sustainable development and integrated them into environmental education, which significantly raised global awareness and recognition of ESD’s importance. At the 70th Session of the United Nations General Assembly in 2015, all 193 Member States adopted the document “Transforming Our World: The 2030 Agenda for Sustainable Development.” Target 4.7 under Sustainable Development Goal 4 (Quality Education) articulates the commitment to “ensure that all learners acquire the knowledge and skills needed to promote sustainable development,” thereby establishing ESD not only as a renewed objective in its current phase but also as an essential element of global educational frameworks [11].

Throughout its evolution, the conceptual emphasis of ESD has expanded from its initial focus on environmental education to emphasizing education’s critical role in integrating economic growth, social equity, and environmental protection. It now also prioritizes the construction of an equitable and sustainable future, advancing toward a vision of sustainable development founded on the harmonious coexistence between humanity and the planet.

1.2. Dual-Teacher Classroom: A New Model of Education for Sustainable Development to Address Urban-Rural Educational Gaps

The Dual-Teacher Classroom has emerged as an innovative model for ESD in China, designed to address systemic equity issues in education between urban and rural areas (Zheng et al., 2021) [10]. By leveraging network technology and synchronous interactive teaching systems, this model connects urban schools with rural schools, facilitating real-time collaboration between teachers from well-resourced and under-resourced institutions. The Dual-Teacher Classroom exemplifies a sustainable approach to resource sharing—it minimizes physical infrastructure costs while maximizing the reach of teacher expertise through cross-regional collaboration (Zheng et al., 2021) [10]. Unlike traditional co-teaching models, which primarily target inclusive education for students with disabilities (Messiou, 2016) [12], the Dual-Teacher Classroom model emphasizes equitable access to high-quality instruction through shared pedagogy and resource redistribution, thereby contributing to sustainable education development.

However, despite its potential, empirical research on the Dual-Teacher Classroom remains limited and often lacks a critical examination of equity outcomes. Existing studies predominantly focus on technical implementations, creating a gap in understanding how teaching equity influences student engagement and the learning effect. For instance, Liu et al. (2022) and Li et al. (2024) described the construction of a Dual-Teacher classroom within intelligent environments, emphasizing technology but overlooking equity dimensions [13,14]. Similarly, Jiang et al. (2025) explored the use of artificial intelligence to enhance participation but did not address how equity perceptions shape classroom effectiveness [15]. In contrast, Coiduras et al. (2020) evaluated the alignment of the Dual-Teacher Classroom with the OTL framework but did not examine the mediating role of equity perceptions [16]. These contradictions highlight the need for a comprehensive analysis of teaching equity mechanisms in Dual-Teacher Classrooms.

1.3. The Framework of Teaching Equity Under the OTL Theory: From Theory to Practice

“Opportunity to Learn” (OTL) is defined as the opportunity for students to encounter the intended curriculum through the implemented curriculum (Hyman et al., 1996) [17]. The Opportunity to Learn (OTL) theory, initially conceptualized by Carroll (1963), posits that equitable learning outcomes depend on students’ access to sufficient time, appropriate

resources, and tailored instruction [18]. Over the decades, OTL has evolved into a multidimensional framework encompassing systemic, institutional, classroom, and student-level factors. Stevens (1993) pioneered a multi-dimensional view of OTL, shifting the focus beyond time to include content coverage and instructional quality [19]. This was further systematized by Schmidt et al. (1996) [20], whose model conceptualized OTL factors across the educational system, school, classroom, and student levels, providing a foundational theory for large-scale assessments like TIMSS and PISA. These assessments operationalized OTL to evaluate the intended curriculum and students' opportunities to apply knowledge in diverse contexts. The framework continued to evolve, incorporating broader socio-cultural dimensions such as teacher–student relationships (Jensen et al., 2016) [21] and the role of leadership in shaping learning opportunities (Urlick et al., 2018) [22].

This expanded conceptualization offers a robust theoretical foundation for analyzing innovative instructional models, including the Dual-Teacher Classroom, where the equitable distribution and effective use of learning opportunities are central concerns. Supporting this approach, Kurz et al. (2014) [23] and Margaret et al. (2019) [24] have highlighted the OTL framework as a valuable tool for examining co-teaching arrangements. Within the Dual-Teacher Classroom model, teaching equity is adopted as a key monitoring indicator for Education for Sustainable Development (ESD). To empirically assess this construct, it is operationalized through three interdependent components derived from the OTL framework as shown in Figure 1, translating the theoretical dimensions into measurable indicators (Lei, 2018) [25]:

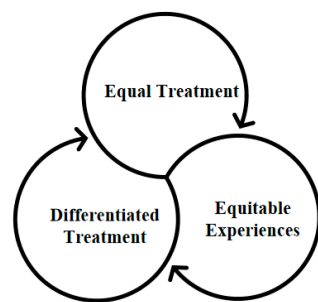


Figure 1. The framework of teaching equity under the OTL theory, illustrating three components, namely equal treatment, differentiated treatment, and equitable experiences, which collectively measure teaching equity in Dual-Teacher Classrooms.

- A. **Equal Treatment:** Ensuring uniform access to learning identities, rights, and resources (Lei, 2018) [25]. However, contemporary research cautions that such procedural uniformity, while foundational, can inadvertently sustain inequities if applied rigidly without considering students' diverse starting points (Kwok et al., 2025) [26].
- B. **Differentiated Treatment:** Adapting instruction to address individual needs, particularly for disadvantaged students (Boaler & Sengupta-Irving, 2016) [3]. Effective differentiation is increasingly framed as a humanizing practice that responds to students' unique cultural and cognitive assets, rather than a mere technical adjustment (Kwok et al., 2025; Phuong et al., 2025) [26,27].
- C. **Equitable Experiences:** Prioritizing students' subjective perceptions of fairness, trust, and satisfaction (Yang & Li, 2016) [28]. This dimension aligns with the growing emphasis on transformative social-emotional learning and "expansive framing," which prioritizes students' sense of belonging, identity, and relevance in the learning process (Yadati et al., 2025; Freedman et al., 2025) [9,29].

Recent studies highlight persistent tensions among these components. For example, while Equal Treatment correlates positively with behavioral engagement (Trainor, 2020) [30],

excessive standardization may fail to address the needs of marginalized students (Xu & Zhao, 2021) [31]. Conversely, Differentiated Treatment has been shown to reduce achievement gaps (Denessen, 2020) [32]. It carries a risk of stigmatizing students if implemented without sufficient sensitivity (Fry, 1983) [33]. These findings underscore that balancing equity with differentiation remains a critical challenge in Dual-Teacher Classroom—particularly in contexts where urban-rural disparities exacerbate existing structural inequities.

1.4. Learning Engagement and Perceived Learning Effect: A Multidimensional Lens

Learning engagement, comprising emotional, behavioral, and cognitive dimensions (Wang et al., 2014) [34]—functions both as an outcome and a mediator of teaching equity. Emotional engagement (e.g., interest and enthusiasm) is highly responsive to perceived fairness (Zheng et al., 2017) [35], while behavioral engagement (e.g., task completion) depends significantly on access to learning resources (Kaltainen et al., 2018) [36]. Cognitive engagement, which involves metacognition and critical thinking, is enhanced when students perceive instructional practices as equitable (Boaler & Sengupta-Irving, 2016) [3].

However, existing research often oversimplifies engagement by treating it as a composite measure (Griffin, 2018) [37], overlooking how its distinct dimensions interact within the Dual-Teacher Classroom for ESD. For instance, while cognitive engagement might be consistently high across student groups during a well-structured synchronous lecture, emotional and behavioral engagement could vary significantly depending on local facilitation and technological access (Li et al., 2024) [14]. Furthermore, Perceived Learning Effect—a subjective evaluation of knowledge acquisition—is theorized as shaped by these multidimensional engagement processes in conjunction with teaching equity (He et al., 2012) [6]. Nevertheless, the specific mediation mechanisms through which equity and the distinct dimensions of engagement collectively influence perceived learning effect remain unexamined in the Dual-Teacher Classroom model.

Despite growing interest in the Dual-Teacher Classroom for ESD, several critical questions remain unexplored:

1. How do urban-rural disparities in Dual-Teacher Classroom for ESD influence students' perceptions of teaching equity?
2. Which dimensions of learning engagement mediate the relationship between teaching equity and perceived learning effect?
3. How does teaching equity contribute to narrowing the gap in perceived learning effect between urban and rural student groups?

Hypotheses

Based on the literature review and the OTL framework for teaching equity, this study proposes the following hypotheses, with learning engagement operationalized through its three dimensions: emotional, behavioral, and cognitive engagement.

H1. *Teaching equity in the Dual-Teacher Classroom positively influences both learning engagement and perceived learning effect.*

H2. *Significant differences exist between the rural group and the urban group in levels of teaching equity, learning engagement, and perceived learning effect, with the urban group expected to report higher values across these constructs.*

H3. *Learning engagement mediates the relationship between teaching equity and perceived learning effect. Specifically, we hypothesize the following:*

H3a. *Teaching equity has a positive influence on learning engagement.*

H3b. *Learning engagement has a positive influence on perceived learning effect.*

H3c. *The indirect effect of teaching equity on perceived learning effect through learning engagement is significant.*

H4. *The mediating effect of learning engagement differs significantly between the rural and urban groups, suggesting that the strength and pattern of mediation vary across educational contexts.*

Figure 2 illustrates the hypothesized model, outlining the structural relationships among teaching equity, learning engagement, and perceived learning effect.

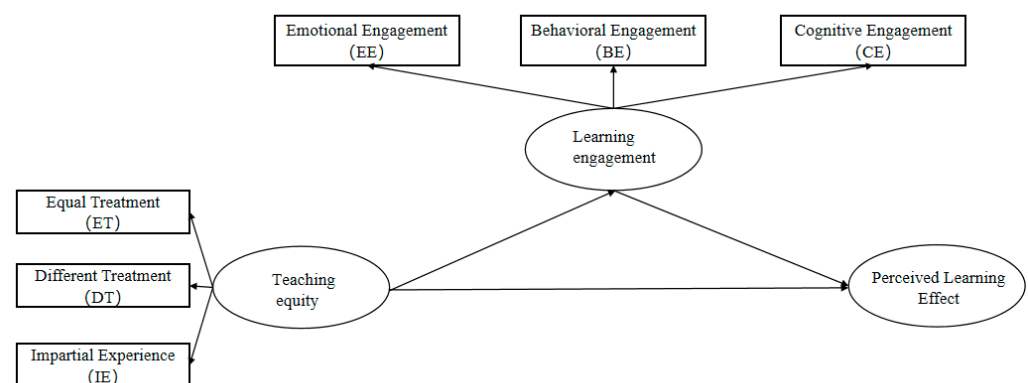


Figure 2. Hypothesis model, showing the proposed relationships among teaching equity, learning engagement, and perceived learning effect.

2. Materials and Methods

2.1. Context of the Study and Participants

The participants in this study were fifth-grade elementary school students from Beijing, enrolled in mathematics classes taught through the Dual-Teacher Classroom for ESD model.

At the beginning of the project, an anonymous survey was administered, the responses of which were collected on-site. Prior to the data collection, informed consent was obtained from both the class teachers and participants. During the session, participants received standardized instructions and were encouraged to ask questions if they had any doubts during the completion process to ensure they understood the content of the questionnaire and could provide accurate responses. A total of 278 students (137 boys, 141 girls) engaged in the Dual-Teacher Classroom model were included, yielding 278 completed questionnaires.

2.2. Research Instrument

Both the rural and urban groups used the same questionnaire. The survey included three sections, namely teaching equity, learning engagement, and perceived learning effect, with a total of 50 questions. All items were measured on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). During the adaptation of existing scales, exploratory factor analysis was performed, and items were adjusted to suit the participants' age characteristics and course requirements.

2.2.1. Dual-Teacher Classroom Teaching Equity Survey

The survey instrument employed in this study was adapted from internationally validated questionnaires, including the PISA Learning Opportunities questionnaire (Xin et al., 2018) [38], Arbaugh et al. (2008) [39], Davis (1989) [40], and Lei (2018) [25], with a focus on teaching equity. The final version of the survey, tailored to the Dual-Teacher

Classroom model, comprises 27 items assessing three constructs: equal treatment, differentiated treatment, and equitable experiences.

2.2.2. Dual-Teacher Classroom Student Learning Engagement Survey

The study adapted the “Learning Engagement Scale” developed by Wang et al. (2014) [34], which categorizes students’ learning engagement into three dimensions: emotional engagement, behavioral engagement, and cognitive engagement. The questionnaire was further customized to fit the context of the Dual-Teacher Classroom, which features blended synchronous teaching by instructors. Emotional engagement denotes positive affective experiences in the classroom, such as interest, enjoyment, and enthusiasm. Behavioral engagement corresponds to observable behaviors, including timely task completion, attention, class participation, questioning, and undertaking challenging tasks. Cognitive engagement involves mental investment, such as meaningful processing, strategy use, sustained attention, and metacognition (Wentzel & Miele, 2009) [41]. The final questionnaire comprises 18 items.

2.2.3. Dual-Teacher Classroom Student Perceived Learning Effect Survey

This study utilized the Perceived Learning Effect Scale by Thomas to develop a survey instrument tailored specifically to students in the Dual-Teacher Classroom context [42]. The final questionnaire comprises 5 items.

A pilot survey of the developed questionnaire is an essential step to examine the appropriateness of its items. Based on the analysis results, the questionnaire was appropriately revised, laying a solid foundation for the formal distribution. Consequently, to ensure the rationality of the research instrument, the researcher randomly selected 158 students from classes not involved in the main experiment as the pilot sample. This sample consisted of 80 boys (50.6%) and 78 girls (49.4%), to whom the questionnaires were distributed and subsequently collected.

The reliability of the collected valid questionnaires was tested using SPSS 26.0 (version 26.0; IBM Corp., Armonk, NY, USA). Cronbach’s alpha coefficient was employed to assess the questionnaire’s reliability, determining its stability and consistency. A threshold of 0.7 is typically used for Cronbach’s alpha, with higher values indicating better internal consistency. In the reliability analysis, the Cronbach’s alpha coefficients for all dimensions of the Teaching Equity scale, the Learning Engagement scale, and the Perceived Learning Effect scale exceeded 0.9. These results indicate excellent reliability and high internal consistency for all sections of the questionnaire, suggesting no need for content adjustments at this stage.

To establish the discriminant validity of the measurement instrument, confirmatory factor analysis (CFA) was conducted. As shown in Table 1, the fit indices for the model were as follows: $\chi^2/df = 1.933$ (<3), RMSEA = 0.058 (<0.08), and values for NFI, RFI, CFI, IFI, and TLI all exceeded 0.9 [43]. These results indicate that the model meets accepted criteria for good fit, thereby supporting the discriminant validity of the three scales within the Dual-Teacher Classroom questionnaire. We further assessed the construct validity of the scales by examining composite reliability (CR), average variance extracted (AVE), and the Heterotrait–Monotrait Ratio (HTMT). As shown in Table 1b, all constructs demonstrated good composite reliability ($CR > 0.7$) and convergent validity ($AVE > 0.5$). The HTMT ratios were below the threshold of 0.90, supporting discriminant validity [44].

Table 1. Reliability analysis of the Dual-Teacher Classroom scales: (a) Overall fit indices of the measurement model for the Dual-Teacher Classroom scales. (b) Psychometric properties of the Dual-Teacher Classroom scales.

	Dimension	N	Cronbach's Alpha	Cronbach's Alpha			
Teaching Equity	Equal Treatment	12	0.964	0.983			
	Differentiated Treatment	7	0.954				
	Equitable Experiences	8	0.961				
Learning Engagement	Emotional Engagement	5	0.950	0.973			
	Behavioral Engagement	5	0.951				
	Cognitive Engagement	8	0.956				
Perceived Learning Effect	-	5	-	0.950			
(a)							
	X ² /df	RMSEA	NFI	RFI	CFI	IFI	TLI
Standard	<3	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Value	1.933	0.058	0.979	0.971	0.989	0.990	0.986
(b)							
Construct	Composite Reliability (CR)	Average Variance Extracted (AVE)	HTMT Range with Other Constructs				
Equal Treatment	0.965	0.712	0.78–0.85				
Differentiated Treatment	0.955	0.698	0.80–0.87				
Equitable Experiences	0.962	0.705	0.82–0.88				
Emotional Engagement	0.951	0.734	0.65–0.75				
Behavioral Engagement	0.952	0.741	0.76–0.84				
Cognitive Engagement	0.957	0.718	0.78–0.85				
Perceived Learning Effect	0.951	0.761	0.70–0.82				

2.3. Data Analysis

To test the hypotheses, data analysis was performed using IBM SPSS (version 26.0) and IBM AMOS (version 24.0). Initially, descriptive statistics were computed with IBM SPSS, followed by independent samples *t*-tests and correlation analysis. We conducted a multigroup structural equation modeling (SEM) analysis to test measurement invariance across rural and urban groups. Configural invariance was established, confirming that the factor structure is equivalent across groups. Given the ordered categorical nature of the Likert-scale data, we employed the robust maximum likelihood (MLR) estimation method, which is appropriate for non-normal and categorical data. Subsequently, structural equation modeling (SEM) was carried out using the PROCESS macro for IBM SPSS and IBM AMOS to examine the relationships proposed in Figure 1. SEM enables the simultaneous examination of all variables in the model, allowing researchers to evaluate whether the model should be retained, rejected, or modified. To enhance the robustness of our analysis, we included gender and class as covariates in the model to control for potential confounding effects. Additionally, we adjusted for clustering at the class level using cluster-robust standard errors to account for intra-class correlations. After fitting the SEM model to the data, path analysis was conducted (Schumacker & Lomax, 2010) [45]. Additionally, the bias-corrected percentile bootstrapping method was applied to test mediation effects, with 5,000 bootstrap samples used to establish confidence intervals for these effects.

3. Results

3.1. Common Method Bias Test

To address potential common method bias, as all variables in this study were assessed using self-report measures, Harman's single-factor test was conducted. The results indicated that five factors had eigenvalues greater than 1, with the first factor accounting for only 36.96% of the variance—below the recommended threshold of 40%. Therefore, common method bias was not a significant concern in this study.

3.2. Descriptive Statistics and Analysis

Descriptive Statistics, Differences, and Correlations

Descriptive statistics for the research variables, including the mean, standard deviation, and significance levels of intergroup differences, are presented in Tables 2 and 3. The analysis revealed statistically significant differences between the rural and urban groups on all variables ($p < 0.05$). Among the sub-variables, however, only emotional engagement did not reach statistical significance ($p = 0.065$, which exceeded the 0.05 threshold), whereas all the other sub-variables demonstrated significant differences ($p < 0.05$), thereby supporting hypothesis H2.

Table 2. Descriptive statistics and intergroup difference analysis of variables for rural and urban groups in the Dual-Teacher Classroom.

Variable	Group	N	Mean	SD	<i>p</i> -Value
Teaching Equity	urban	176	4.771	0.427	0.003
	rural	102	4.590	0.506	
Learning Engagement	urban	176	4.725	0.469	0.002
	rural	102	4.536	0.523	
Perceived Learning Effect	urban	176	4.722	0.525	0.013
	rural	102	4.551	0.591	

Table 3. Descriptive statistics and intergroup difference analysis of sub-variables for rural and urban groups in the Dual-Teacher Classroom.

Sub-Variable	Group	N	Mean	SD	<i>p</i> -Value
Equal Treatment	urban	176	4.777	0.430	0.005
	rural	102	4.612	0.518	
Differentiated Treatment	urban	176	4.748	0.487	0.003
	rural	102	4.559	0.550	
Equitable Experiences	urban	176	4.790	0.420	0.001
	rural	102	4.598	0.518	
Emotional Engagement	urban	176	4.673	0.637	0.065
	rural	102	4.531	0.573	
Behavioral Engagement	urban	176	4.759	0.475	0.001
	rural	102	4.537	0.546	
Cognitive Engagement	urban	176	4.742	0.434	0.001
	rural	102	4.539	0.531	

A key assumption for performing regression analysis and specifying mediation models is the presence of significant correlations among variables (Preacher et al., 2007) [46]. This study examined the correlations among all variables and sub-variables. As shown in Tables 4 and 5, all correlation coefficients were statistically significant. Strong associations were observed among teaching equity, learning engagement, and perceived learning effect. Notably, the strongest correlation was identified between teaching equity and perceived learning effect, exceeding 0.8, underscoring its critical role. Among the sub-variables,

emotional engagement demonstrated a moderate correlation with perceived learning effect, while other variables exhibited stronger relationships with perceived learning effect, thereby supporting hypothesis H1. These results suggest that although all components contribute to perceived learning effect, the association with emotional engagement was less robust compared to other dimensions.

Table 4. Correlations between sub-variables and perceived learning effect in the Dual-Teacher Classroom.

	1	2	
Teaching Equity	1.000		
Learning Engagement	0.808 **	1.000	
Perceived Learning Effect	0.762 **	0.793 **	1.000

Note: ** At level 0.01 (two-tailed), a significant correlation.

Table 5. Correlation between sub-variables and perceived learning effect in the Dual-Teacher Classroom.

	1	2	3	4	5	6	7
ET	1.000						
DT	0.857 **	1.000					
EE	0.888 **	0.893 **	1.000				
EEt	0.608 **	0.603 **	0.626 **	1.000			
BE	0.752 **	0.761 **	0.787 **	0.763 **	1.000		
CE	0.787 **	0.793 **	0.823 **	0.725 **	0.888 **	1.000	
PLE	0.715 **	0.733 **	0.745 **	0.652 **	0.790 **	0.782 **	1.000

** At level 0.01 (two-tailed), a significant correlation. ET: Equal Treatment; DT: Differentiated Treatment; EE: Equitable Experiences; EEt: Emotional Engagement; BE: Behavioral Engagement; CE: Cognitive Engagement; PLE: Perceived Learning Effect.

3.3. Mediating Effects and Heterogeneity in Dual-Teacher Classroom

To examine the model shown in Figure 2, we employed SPSS PROCESS Model 4 to test the mediation model, with a focus on the effects of teaching equity and learning engagement on perceived learning effect in the Dual-Teacher Classroom. This model was analyzed separately for different student groups, specifically comparing students from the rural and urban groups participating in the Dual-Teacher Classroom. The mediation analysis results for the urban and rural groups are presented in Figures 3 and 4.

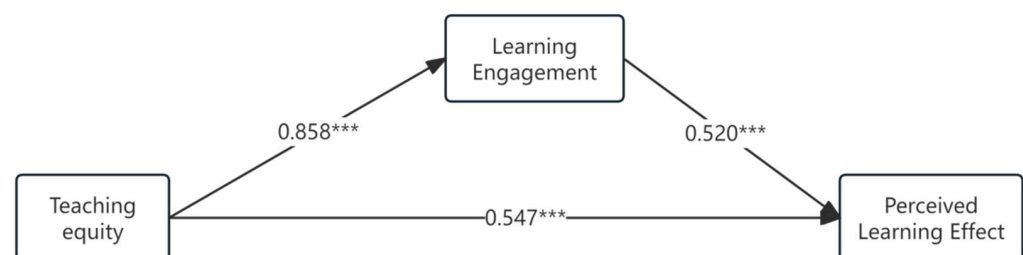


Figure 3. Mediation model for urban group showing partial mediation of learning engagement between teaching equity and perceived learning effect. *** $p < 0.001$.

The results of the mediation effect decomposition for the urban group are summarized in Table 6. Bootstrap analysis of urban mediation effects showed that the total effect of teaching equity on perceived learning effect was 0.993, and the direct effect was 0.547, with a bootstrap 95% CI of [0.396, 0.699]. The results indicate that, even after including the mediating variable of learning engagement, teaching equity still exerted a significant direct effect on perceived learning effect, accounting for 55.086% of the total effect. Learning engagement played a significant mediating role between teaching equity on perceived

learning effect, with an indirect effect value of 0.446 (bootstrap 95% CI of [0.179, 0.744]), representing 44.914% of the total effect.

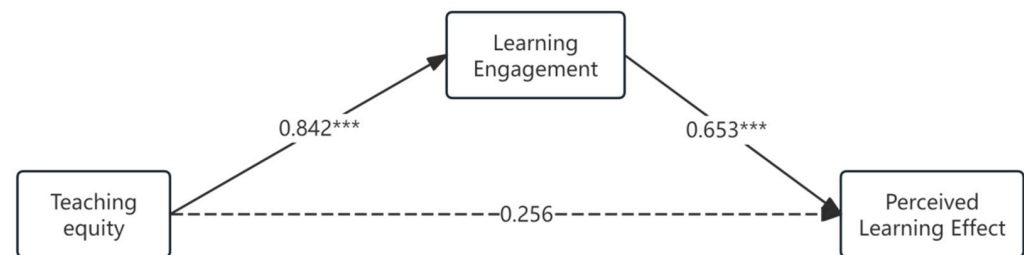


Figure 4. Mediation model for the rural group showing partial mediation of learning engagement between teaching equity and perceived learning effect. *** $p < 0.001$; dashed lines represent non-significant paths.

Table 6. Urban group's total effect, direct effect, and mediation effect decomposition.

	Estimate	se	LLCI	ULCI	% of Total
Total Effect	0.993	0.055	0.885	1.101	-
Direct Effect	0.547	0.077	0.396	0.699	55.086%
Indirect Effect	0.446	0.145	0.179	0.744	44.914%

Model R^2 for perceived learning effect = 0.621.

These findings suggest that while teaching equity has a direct impact on perceived learning effect, learning engagement also significantly mediates this relationship, explaining a substantial portion of the total effect.

The results of the mediation effect decomposition for the urban group are summarized in Table 7. The bootstrap analysis of the mediation effect for the rural group indicates that the total effect of teaching equity on perceived learning effect was 0.806, with a direct effect of 0.256 and a bootstrap 95% CI of [−0.012, 0.523]. This suggests that, after including learning engagement as a mediator, the direct effect of teaching equity on perceived learning effect was not statistically significant, accounting for only 31.762% of the total effect. In contrast, the mediation effect of learning engagement between teaching equity and perceived learning effect was significant, with an indirect effect of 0.550 (bootstrap 95% CI of [0.137, 1.054]), representing 68.238% of the total effect. These results imply that the influence of teaching equity on perceived learning effect is fully mediated by learning engagement.

Table 7. Rural group's total effect, direct effect, and mediation effect decomposition.

	Estimate	se	LLCI	ULCI	% of Total
Total Effect	0.806	0.087	0.634	0.978	-
Direct Effect	0.256	0.135	−0.012	0.523	31.762%
Indirect Effect	0.550	0.239	0.137	1.054	68.238%

Model R^2 for perceived learning effect = 0.587.

A comparison between the urban and rural groups reveals that learning engagement functions as a significant mediator in both student groups, thereby supporting hypothesis H3. However, its mediating role differs: it exhibits partial mediation in the urban group, whereas it acts as a complete mediator in the rural group. This observed distinction validates Hypothesis H4.

3.4. Dual-Teacher Classroom Structural Equation Model and Heterogeneity

To further investigate the relationships between the three sub-variables of teaching equity—equal treatment, differentiated treatment, and equitable experiences—and the three

sub-variables of learning engagement—emotional engagement, cognitive engagement, and behavioral engagement—with perceived learning effect, the hypothesized model was expanded to incorporate the corresponding sub-variable structure. Following necessary path modifications, the results indicated that the refined sub-structural equation model demonstrated good fit, with fit indices as follows: $\chi^2/df = 2.173$ (<3), RMSEA = 0.065 (<0.08), and NFI, RFI, CFI, IFI, TLI all exceeding 0.9. These values conform to established standards of good model fit, thereby supporting the validity of the proposed model.

Based on the standardized hypothesis testing results of the sub-variable structural equation model (as presented in Figure 5), all path coefficients were positive. Specifically, the three sub-variables of teaching equity—equal treatment, differentiated treatment, and equitable experiences—exerted significant positive effects on the three sub-variables of learning engagement: emotional engagement, behavioral engagement, and cognitive engagement. Furthermore, behavioral engagement was found to have a significantly positive influence on perceived learning effect, whereas the influence of the remaining paths was not statistically significant.

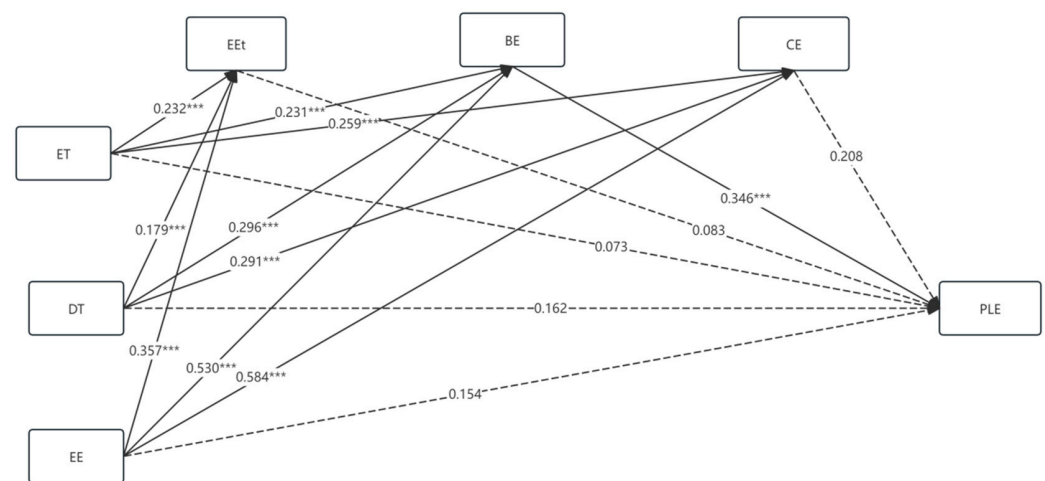


Figure 5. Path diagram of the sub-variable structural equation model. ET: Equal Treatment; DT: Differentiated Treatment; EE: Equitable Experiences; EET: Emotional Engagement; BE: Behavioral Engagement; CE: Cognitive Engagement; PLE: Perceived Learning Effect. *** $p < 0.001$; dashed lines represent non-significant paths.

To further examine potential differences in sub-variable pathways between urban and rural group students, separate structural equation models were developed and tested for each cohort.

Prior to conducting the multigroup path analysis, a series of measurement invariance tests were performed to ensure that the constructs were measured equivalently across the rural and urban groups, which is a critical prerequisite for meaningful cross-group comparisons. We followed a sequential constraint approach, testing configural, metric, and scalar invariance. The configural invariance model, which imposes the same factor structure across groups without constraining parameters, demonstrated good fit ($\chi^2/df = 2.866$, CFI = 0.977, TLI = 0.956, RMSEA = 0.057), indicating that the basic model structure is equivalent. The metric invariance model, which constrains factor loadings to be equal across groups, did not result in a significant deterioration of model fit compared to the configural model ($\Delta CFI = -0.008$, $\Delta RMSEA = 0.002$), supporting metric invariance, which meets the recommended criteria of $\Delta CFI < 0.010$ and $\Delta RMSEA < 0.015$ for invariance establishment. The establishment of metric invariance confirms that participants from both groups attribute the same meaning to the latent constructs, thus justifying the subsequent comparison of regression paths (structural coefficients) between the rural and urban groups.

This confirms that the constructs are being measured on the same scale and that the items relate to the latent factors in the same way for both rural and urban students, allowing for the comparison of structural paths and correlations in the subsequent multigroup analysis.

According to the path diagram results for the urban group (as presented in Figure 6), all path coefficients were positive. Specifically, equal treatment demonstrated significant positive effects on emotional engagement, behavioral engagement, and cognitive engagement. Similarly, equitable experiences significantly and positively influenced behavioral engagement, cognitive engagement, and perceived learning effect. However, the other path coefficients did not reach statistical significance.

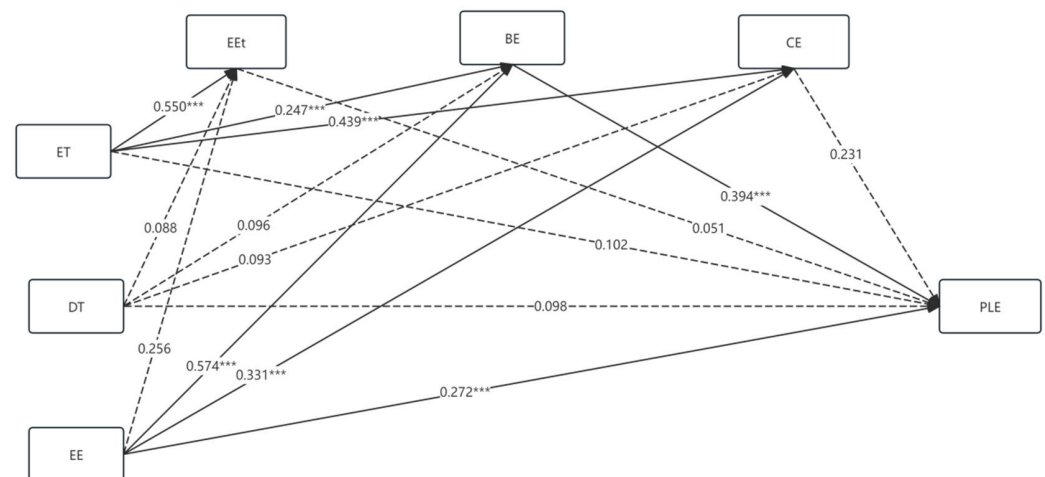


Figure 6. Path diagram of the sub-variable structural equation model for the urban group. ET: Equal Treatment; DT: Differentiated Treatment; EE: Equitable Experiences; EEt: Emotional Engagement; BE: Behavioral Engagement; CE: Cognitive Engagement; PLE: Perceived Learning Effect. *** $p < 0.001$; dashed lines represent non-significant paths.

According to the path diagram results for the rural group (as shown in Figure 7), most path coefficients were positive; however, a small number of paths indicated that equal treatment had a negative, though non-significant, effect on emotional engagement and cognitive engagement. In contrast, both differentiated treatment and equitable experience showed significant positive effects on emotional engagement, behavioral engagement, and cognitive engagement. The remaining path coefficients were not statistically significant. Among these, equitable experience exerted the strongest influence on emotional engagement within the rural group, differentiated treatment had the greatest effect on behavioral engagement, and differentiated treatment also demonstrated the strongest impact on cognitive engagement.

A comparison of the path coefficients between the structural equation models for the rural and urban groups revealed variations across certain paths. To further investigate the specific paths where these differences occur and to explore potential underlying causes, this study performed a path-specific heterogeneity analysis, as summarized in Table 8.

From Table 8, it can be observed that for the paths ET → EE, ET → BE, and ET → CE, the urban group exhibits significant positive effects. This indicates that, for urban students, equal treatment significantly and positively influences learning engagement. In contrast, these paths demonstrate weaker effects within the rural group; even slight negative effects are observed in the paths ET → EEt and ET → CE.

Regarding the paths DT → EEt, DT → BE, and DT → CE, the rural group appears more responsive to differentiated treatment. Specifically, differentiated treatment has a significant positive impact on emotional, behavioral, and cognitive engagement among rural students, highlighting its critical importance for this group. This finding resonates

with the concept of “humanizing approaches” to equity, which argues that recognizing and responding to individual and contextual needs is paramount for marginalized students (Kwok et al., 2025) [26]. It suggests that for rural students, who may be at a systemic disadvantage, the act of being seen and personally supported by the teacher is a critical component of perceiving the classroom as equitable. In comparison, the effects of differentiated treatment on the same variables, though still positive, are less pronounced within the urban group.

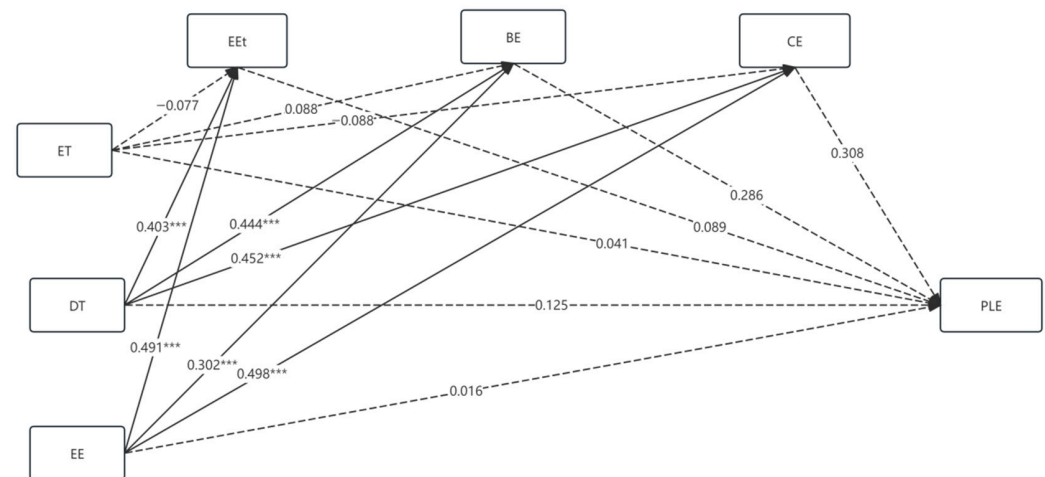


Figure 7. Path diagram of the sub-variable structural equation model for the rural group. ET: Equal Treatment; DT: Differentiated Treatment; EE: Equitable Experiences; EEt: Emotional Engagement; BE: Behavioral Engagement; CE: Cognitive Engagement; PLE: Perceived Learning Effect. *** $p < 0.001$; dashed lines represent non-significant paths.

Table 8. Heterogeneity analysis of each path.

Path	Rural Group	Urban Group
ET → EEt	−0.077	0.550 ***
ET → BE	0.088	0.247 ***
ET → CE	−0.088	0.439 ***
DT → EEt	0.403 ***	0.088
DT → BE	0.444 ***	0.096
DT → CE	0.452 ***	0.093
EE → EEt	0.491 ***	0.256
EE → BE	0.302 ***	0.574 ***
EE → CE	0.498 ***	0.331 ***
EEt → PLE	0.089	0.051
BE → PLE	0.286	0.394 ***
CE → PLE	0.308	0.231
ET → PLE	0.041	0.102
DT → PLE	0.125	0.098
EE → PLE	0.016	0.272 ***

*** $p < 0.001$.

Regarding the path EE → EEt, the influence within the rural group exceeds that of the urban group. Meanwhile, for the paths BE → PLE and EE → PLE, behavioral engagement and equitable experience exert significant positive effects on perceived learning effect among urban students. However, these significant positive effects were not observed in the rural group.

4. Discussion

This study focuses on the Dual-Teacher Classroom, an instructional organizational model designed to promote sustainable education. Within the OTL framework of teaching

equity, it investigates the mechanisms and pathways through which equal treatment, differentiated treatment, and equitable experience—key observational indicators within ESD—along with student learning engagement, encompassing emotional, cognitive, and behavioral engagement, influence perceived learning effect. Within the context of the Dual-Teacher Classroom model examined in this study, the findings offer a clearer understanding of how teaching equity practices within sustainable education contribute to students' perceived learning effect. All four research hypotheses proposed in this study were fully supported by the empirical results.

4.1. Significant Differences in Teaching Equity, Learning Engagement, and Perceived Learning Effect Between Rural and Urban Students in Dual-Teacher Classroom

Within the Dual-Teacher Classroom for ESD, notable disparities were observed in teaching equity, learning engagement, and perceived learning effect between rural and urban students, with urban students demonstrating significantly higher effects. Students in rural settings participate in online learning, where language and text serve as the primary channels for both vertical and horizontal information transmission. However, this process is accompanied by information loss. Information loss refers to a degradation in either the quality or quantity of information. Quality loss occurs when information becomes distorted and thereby diminishes in value, whereas quantity loss involves a reduction in the amount of meaningful content (Xiao, 1995) [47]. Consequently, rural students receive diminished instructional content, while urban students, being closer to the information source, experience minimal loss. This imbalance leads to significant differences in teaching equity between the two groups. Since equity varies substantially at the source, subsequent differences in learning engagement and perceived learning effect naturally follow. Interestingly, at the sub-dimension level, no significant difference in emotional engagement was found between rural and urban students. This suggests that, despite some degradation in teaching equity during the transmission process characteristic of the Dual-Teacher Classroom, the model succeeds in fostering students' emotional participation, reflecting a strong student appetite for sustainable education. Therefore, based on our findings, it appears crucial to enhance teachers' equitable teaching practices within this specific Dual-Teacher Classroom model. This might involve building professional collaborative communities, and establishing relationships based on mutual trust is crucial (Truijen et al., 2013; Bacharach et al., 2010) [48,49]. Real-time sharing of student learning conditions—while maintaining emotional engagement—can facilitate differentiated cooperative instruction tailored to student needs, thereby helping to promote balanced, high-quality educational resources and eliminate disparities in teaching equity between rural and urban students. This objective is central to the core mission of the ESD. For instance, studies in other countries (e.g., Bacharach et al., 2010) have shown that teacher collaboration and professional development programs can enhance equity in co-teaching models [49]. These findings suggest that similar approaches could be adapted in Dual-Teacher Classrooms globally to address educational disparities.

4.2. Teaching Equity in the Dual-Teacher Classroom Has a Significant Positive Effect on Perceived Learning Effect, with Equitable Experiences as the Strongest Sub-Dimension

Teaching equity in the Dual-Teacher Classroom for ESD exerts a significant positive impact on perceived learning effect, with the equitable experiences sub-dimension demonstrating the strongest influence. This finding is consistent with previous research (Mislevy et al., 2018) [50] and is strongly reinforced by recent work on “productive disciplinary engagement,” which links deep learning to environments where students feel their contributions are valued and legitimized (Freedman et al., 2025) [9]. Equitable experiences encompass trust, fairness, and satisfaction—dimensions associated with the extent to which

students feel recognized and valued within classroom instruction (Yang & Li, 2016) [28]. Therefore, the Dual-Teacher Classroom should prioritize enhancing students' equitable experiences, continually improving course implementation, and building meaningful connections between course content and students' prior knowledge to facilitate deep engagement among all students (Yu, 2023) [51]. In the Dual-Teacher Classroom, teaching equity goes beyond the mere equal distribution of learning opportunities by teachers as a form of procedural fairness. Rather, it entails ensuring that students experience genuine fairness in learning opportunities, acknowledging each student's central role in the classroom, and transitioning from formal to substantive equity. Moreover, it has been observed that Dual-Teacher Classrooms can occasionally result in classroom disorganization or a lack of feedback on student contributions (Li et al., 2024) [14], which may diminish students' learning enthusiasm, reduce their sense of presence, and weaken their equitable experiences. Therefore, it is essential for teachers to align teaching elements effectively, optimize instructional methods, and reinforce a student-centered educational philosophy to better fulfill the intended function of the Dual-Teacher Classroom. Our findings, viewed through the lens of recent scholarship (Goldin et al., 2025) [8], suggest that successful implementation of Dual-Teacher Classrooms requires moving "Beyond Technical Fixes." It is not enough to simply connect two classrooms technologically; the pedagogical and relational practices within that technological framework must be deliberately designed to foster substantive, rather than superficial, equity.

4.3. Teaching Equity in the Dual-Teacher Classroom Significantly Influences Perceived Learning Effect Through the Mediation of Learning Engagement, with Variation in Effects Between Rural and Urban Groups

In the Dual-Teacher Classroom for ESD, learning engagement serves as a significant mediator, indicating that teachers should focus not only on students' engagement but also on their own equitable instructional practices. Both teacher and student actions collectively contribute to enhancing overall teaching effectiveness within this model. However, mediation analysis between rural and urban groups reveals notable differences: for the urban group, teaching equity partially enhances perceived learning effect through learning engagement, while also retaining a significant direct effect. In contrast, for the rural group, the influence of teaching equity on perceived learning effect is fully mediated by learning engagement, with no significant direct path observed. This discrepancy, as observed in our sample, underscores a potential latent inequity between student groups in the Dual-Teacher Classroom structure we studied. This discrepancy aligns with previous studies (e.g., King-Sears & Strogilos, 2020), indicating that structural inequities amplify mediation differences in disadvantaged groups [52]. The full mediation in rural students suggests that learning engagement is a critical pathway for improving perceived learning effect in resource-limited contexts. Internationally, these findings highlight the need for culturally adaptive strategies in Dual-Teacher Classrooms to address global educational disparities. The difference may stem from the fact that urban students, being at the source of high-quality educational resources, experience teaching equity in two distinct ways: (1) a baseline level of fairness established through long-term student–teacher collaboration, forming a fairness threshold, and (2) enhanced teaching equity resulting from teachers' heightened emphasis on fairness within the Dual-Teacher setting, which surpasses this threshold and is perceptible to students. When urban students perceive teaching equity below this threshold, entrenched cognitive patterns may lead them to underestimate the role of learning engagement, whereas equity levels exceeding the threshold facilitate improved perceived learning through engagement. Therefore, teachers in the Dual-Teacher Classroom should recognize the heterogeneity in students' fairness thresholds. Efforts should be made to ensure fundamental equity while progressively elevating teaching equity for rural

students to raise their fairness threshold, thereby mitigating intergroup disparities. Such an approach could be a promising direction for helping to transcend procedural fairness and work towards substantive equity. Furthermore, teachers should refine synchronized teaching practices to ensure that both rural and urban students perceive equitable instructional treatment, ultimately supporting sustainable educational development for all.

4.4. Structural Equation Model Pathways Differ Between Rural and Urban Students in the Dual-Teacher Classroom, with Equal Treatment in Teaching Equity and Learning Engagement Exhibiting Significant Positive Effects for Urban but Not Rural Students

In the Dual-Teacher Classroom for ESD, differences are observed in the paths linking Equal Treatment (ET) to the dimensions of Learning Engagement—Emotional Engagement (EEt), Behavioral Engagement (BE), and Cognitive Engagement (CE)—between rural and urban students. This indicates that even under comparable teaching equity conditions, significant disparities in learning engagement persist across these groups. Due to differences in the initial learning conditions of rural and urban students (King-Sears & Strogilos, 2020) [52], a substantial time gap exists in how each group absorbs the same knowledge. Systemic inequities, such as the absence of real-time interaction, further amplify these disparities. When teachers allocate equal learning time or questioning opportunities to all students, those in rural areas—who often require more time to comprehend the material—may be advanced to new content before fully mastering current concepts, thereby intensifying pre-existing inequalities. This often leads to disengagement and reduced learning engagement among rural students. Conversely, in the paths linking Differentiated Treatment (DT) to Learning Engagement (EEt, BE, and CE), teaching equity shows a significant positive effect across all engagement dimensions for the rural group—unlike the urban group. This suggests that when rural students receive additional guidance and tailored learning time, inherent inequities can be mitigated, resulting in truly equitable treatment. Such an approach enhances comprehension and strengthens engagement, underscoring that the goal of teaching equity in the Dual-Teacher Classroom is not absolute equality, but comparative fairness (Temkin, 2017) [53]. Teachers should therefore account for differences in students' learning starting points and provide differentiated support to ensure balanced and substantive equity. Moreover, communication in the Dual-Teacher Classroom constitutes a two-way interactive process wherein students, as active participants, selectively engage with content based on their individual needs and perspectives (Guo, 2016) [54]. Therefore, teachers should prioritize individual learning needs, implement differentiated instruction that leverages students' strengths, and ensure sustainable educational development while addressing diversity. These strategies will ultimately enhance the perceived learning effect and optimize the functionality of the Dual-Teacher Classroom.

5. Conclusions

Based on the OTL teaching equity framework, which serves as an observational indicator for ESD, this study empirically examines primary school students in sustainable development settings in Beijing, China. It investigates the relationships among teaching equity, learning engagement, and perceived learning effect within the Dual-Teacher Classroom model. The results reveal significant disparities in teaching equity, learning engagement, and perceived learning effect between rural and urban students. Teaching equity exerts a significant positive effect on perceived learning effect, both directly and indirectly through the mediation of learning engagement. Notably, the mediating effects differ meaningfully between rural and urban student groups. The study further demonstrates that students play an actively positive role in the relationship between teaching equity, learning engagement, and perceived learning effect, with these effects varying across rural and urban contexts. Based on these findings, the following recommendations are pro-

posed: further promote teachers' equitable instructional behaviors within the Dual-Teacher Classroom; establish professional collaborative communities and foster mutually trusting cooperative relationships to eliminate disparities in teaching equity between rural and urban students; enhance students' equitable experiences and improve the synchronization of teaching processes; acknowledge variations in students' fairness thresholds and gradually increase equity support for rural students to elevate their fairness threshold, thereby transitioning from formal to substantive equity while maintaining fundamental fairness; and adopt a student-centered approach through differentiated instruction that responds to individual needs, ensuring fair yet tailored support that promotes sustainable development and improves overall educational quality. Future research should build on these findings by incorporating the nuanced lenses for characterizing equitable teaching that are emerging in the literature (Phuong et al., 2025) [27]. This could involve observational studies to document the specific teacher moves that create equitable experiences, and intervention studies that design and test professional development programs aimed at helping dual-teacher pairs implement the humanizing and transformative practices called for by contemporary equity scholars (Kwok et al., 2025; Yadati et al., 2025) [26,29].

6. Limitations and Future Research

While this study provides valuable insights into the mechanisms of teaching equity in Dual-Teacher Classrooms, several limitations should be acknowledged. First, the study was conducted in a specific educational context (elementary schools in Beijing), and all participants were fifth-grade students. This limits the generalizability of the findings to other regions, cultural settings, or grade levels. Future research should validate these findings across more diverse geographical and demographic contexts. The data were primarily based on student self-reports, which, despite showing no severe common method bias, may be subject to social desirability and recall biases. The use of perceptual measures for variables like teaching equity and learning effect, while appropriate for capturing student experiences, does not equate to objective measures of instructional quality or learning gains. Future studies could benefit from incorporating multimodal data, such as classroom observations, teacher reports, and objective achievement tests, to triangulate the findings.

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Institutional Review Board Statement: Ethical review and approval were waived for this study by the Ethics Review Committee of the Elementary Education College at Capital Normal University due to the National Health Commission's Ethical Review Measures for Biomedical Research Involving Humans of the People's Republic of China and the World Medical Association's Declaration of Helsinki.

Informed Consent Statement: Informed consent for participation was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

OTL	Opportunity to Learn
ESD	Education for Sustainable Development
ET	Equal Treatment
DT	Differentiated Treatment
EE	Equitable Experiences
EEt	Emotional Engagement
BE	Behavioral Engagement
CE	Cognitive Engagement
PLE	Perceived Learning Effect

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