

**Teachers' Education for Sustainable Development Practice
and Students' Environmental Awareness in Science
: Evidence from TIMSS 2023**

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ABSTRACT

This study examines the effects of teachers' Education for Sustainable Development (ESD) practices on students' environmental awareness using TIMSS 2023 science data. Multiple regression analysis was conducted to analyze cross-national differences and the moderating effect of teacher professional development on relationship between teachers' ESD practices and students' environmental awareness.

Keyword: Education for Sustainable Development, Environmental Awareness, TIMSS 2023, Science, Professional development

a) Purpose of Study

The 2015 Incheon Declaration on SDG 4 (The education sector) emphasized lifelong learning, vocational education, education for vulnerable groups, and education for sustainable development (ESD) by 2030 (UNESCO, 2016). ESD is an educational effort that seeks to shift from a human-centered perspective toward one emphasizing the relationship, coexistence and sustainability between humans and nature (Jickling & Sterling, 2017). In particular, growing concerns such as the climate crisis and environmental pollution have increased the importance of ESD in schools (Benavot & McKenzie, 2024). Accordingly, ESD has been increasingly implemented across countries (UNESCO, 2026), and teachers have generally recognized the necessity of ESD (Lee, 2025; Langman et al., 2024; Borg et al., 2012).

However, not all countries have actively institutionalized ESD within their educational systems. Although long-term professional development opportunities have been shown to positively influence teachers' ESD practices (Pauw et al., 2022), some countries continue to experience insufficient curriculum integration and limited policy support for ESD (Lee, 2025; Smelkova & Trofymenko, 2024). In addition, previous studies have shown that higher levels of teachers' ESD self-efficacy are associated with stronger sustainability-related behavioral intentions among students (Scharenberg et al., 2021). These findings suggest that the teacher' ESD practices and professional development efforts may influence students' environmental awareness. Therefore, it is necessary to examine how teachers' ESD affect student' environmental awareness and in particular whether teacher' professional development moderate relationship.

Empirical studies related to ESD can generally be categorized into research on teachers' perceptions of ESD (Lee, 2025; Borg et al., 2012) and research on the effectiveness of ESD (Pauw et al., 2026; Katsimpelis et al., 2026). However, previous studies have mainly relied on qualitative approaches (Stouthart et al., 2025; Aikens et al., 2018). Existing research has tended to focus on teachers' perceptions and the difficulties encountered during ESD implementation, while international empirical studies examining the effects of teachers' ESD practices on students' environmental awareness remain relatively limited. Therefore, this study aims to analyze the effects of teachers' ESD practices and professional development efforts on students' environmental awareness in order to empirically examine the educational effectiveness of ESD and provide policy implications. The research questions are as follows.

1. What are the cross-national differences in teachers' ESD practices?

2. How does effects of teachers' ESD practices on students' environmental awareness?
3. Does the effort of teacher professional development moderate the relationship between teachers' ESD practices and students' environmental awareness?

b) Research Methods

The data used in this study were drawn from the 2023 Trends in International Mathematics and Science Study (TIMSS), conducted by the International Association for the Evaluation of Educational Achievement. The participants included fourth- and eighth-grade students (fifth and ninth grade in New Zealand, Norway, the United Kingdom, and South Africa due to differences in national education systems). The TIMSS 2023 dataset consists of 12,955 schools, 395,961 students, and 24,845 teachers at the fourth-grade level, and 9,406 schools, 323,920 students, and 39,983 teachers at the eighth-grade level. The large-scale and internationally comparative nature of the dataset makes it appropriate for examining the effects of teachers' ESD practices on students' environmental awareness.

Multiple regression analysis based on the ordinary least squares (OLS) method was employed in this study. An interaction term was included to examine the moderating effect of teacher professional development. The equation is as follows.

< The equation>

$$y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 (X_{1i} \times X_{2i}) + \sum \beta_k control_{ki} + \epsilon_i$$

Table 1. Variable description

Variable Name		Variable Description
Dependent variable	Student awareness	Environmental knowledge plausible value 1-5
Independent variable	Teaching	Average of four values (Never or almost never (1), A few times a year (2), Once or twice a month (3), At least once a week (4) * reverse scoring)
	Teach issue	Sum of four values (Yes (1), No (0))
Moderator	Professional	Yes (1), No (0)

variable		development	
Control variable	Teacher	Sex	Male (1), Female (0)
		Age	under 25 (1), 25-29 (2), 30-39 (3), 40-49 (4), 50-59 (5), 60 or more (5)
		Level of formal Education Completed	ISCED Level 3(1), ISCED Level 4(2), ISCED Level 5(3), ISCED Level 6(4), ISCED Level 7(5), ISCED Level 8(6)
	Home	Amount of Books in your home	None or very few (0–10 books) (1), Enough to fill one shelf (11–25 books) (2), Enough to fill one bookcase (26–100 books) (3), Enough to fill two bookcases (101–200 books) (4), Enough to fill (5)
	School	School Environment	Disagree a lot (1), Disagree little (2), Agree little, (3), Agree a lot (4) * reverse scoring
		School Location	Urban–Densely populated (1), Suburban–On fringe or outskirts of urban (2), Medium size city or large town (3), Small town or village (4), Remote rural (5)
	Nation	EPI 2022	Environmental Performance Index
		Curriculum Policy	Yes (1), No (0)

c) Results and Discussion

The expected main results and implication of this study are as follows. First, cross-national differences are expected in the level of teachers' ESD practices. Teachers' ESD practices are expected to be relatively lower in countries where ESD has not been sufficiently institutionalized within national curricula and educational policies. These findings suggest that institutional and policy support is important in promoting the effective implementation of ESD in schools.

Second, teachers' ESD practices are expected to have a positive effect on students' environmental awareness. This suggests that teachers' ESD practices influence students' environmental awareness and highlights the need to encourage and support teachers' implementation of ESD in schools.

Third, the relationship between teachers' ESD practices and students' environmental awareness is expected to become statistically significant when teachers actively participate in

professional development related to ESD. This implies that supportive conditions and opportunities for teachers' professional development are necessary to strengthen the effectiveness of ESD.

Therefore, this study suggests that efforts at the teacher, curriculum, and school levels are necessary to promote students' environmental awareness and enhance the educational effectiveness of ESD.

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