

Gender and Grade DIF Analysis of Elementary School Students' Ecological Awareness Instrument

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Abstract

The use of ecological awareness instruments in educational settings raises significant concerns regarding measurement fairness across different demographic groups. This study aims to identify items that exhibit differential item functioning (DIF) in an ecological awareness instrument administered to elementary school students. Data were collected from 623 elementary school students in Nusa Penida, consisting of 329 boys and 294 girls across Grades 4 to 6. The instrument was analyzed using Item Response Theory (IRT) with the Generalized Partial Credit Model (GPCM), and DIF was detected using the *lordif* package in R. Results indicate that six items exhibited gender-based DIF, predominantly in the environmental participation dimension, while five items showed grade-based DIF, primarily within the environmental knowledge dimension. Female students demonstrated higher levels of ecological awareness than male students across all grade levels. These findings highlight the importance of selecting items that are equally interpretable across gender and grade groups to ensure fair and valid assessment of ecological awareness in elementary schools.

Keywords: Ecological Awareness; DIF; IRT; Primary School; Gender Bias

Introduction

The challenge in 21st-century learning is to equip students with the knowledge, attitudes, and responsibilities needed to address current and future challenges. One of the major challenges of this era is achieving sustainable development that is environmentally friendly. Urgent global issues of the 21st century can be grouped into four categories: (1) social and economic issues, namely inequality and poverty; (2) ecological issues, namely population growth, bio-energy contamination, natural resource crises, and the breakdown of global ecosystems; (3) ethical issues, namely contradictions between world religions; and (4) epistemological issues, namely the discrepancy between proficiency and education (Parfilova & Kalimullin, 2014).

In response to these pressing global challenges, recent educational literature has heavily emphasized the integration of environmental awareness into primary education curricula worldwide. Various pedagogical innovations, ranging from integrated eco-STEM approaches and thematic team-teaching (Pada et al., 2025; S.C.K., 2026) to mixed-method ecological learning strategies (Kuchkinov et al., 2026), have been rapidly adopted to foster ecological competencies in young learners. As the emphasis on pro-environmental behaviors and sustainability engagement grows throughout the primary education stages (Crespo-Martín et al., 2026; Muñoz-Losa et al., 2025; Paula et al., 2026), the need for robust, multidimensional instruments to measure these eco-social competences accurately has become increasingly

critical (Fuertes Camacho et al., 2025). Establishing measurement fairness through psychometric evaluation is paramount to ensure that such assessments accurately reflect students' actual environmental awareness regardless of their demographic background.

Learning related to ecology has been widely applied, from community settings to formal education. The theory of learning ecology helps link individual-level learning to broader social

and environmental change. The ecological perspective on learning and education focuses on transformation at different levels (Tidball & Krasny, 2011). Ecological learning can provide students with contextual experiences both inside and outside the classroom—in the school yard or in the surrounding environment. At the elementary school level, students are progressively taught to take responsibility for maintaining the cleanliness of the classroom and the broader school environment. This cultivates the understanding that cleanliness is an essential aspect of human life, encouraging children to develop personal responsibility from an early age. Luhmann (1989) argues that it is necessary to expand ecological communication through education by introducing new attitudes, evaluative processes, and environmental capabilities.

Moore (1971) notes that while the term “ecology” is widely discussed, it is often defined so abstractly—through terms such as “ecological consciousness” and “environmental awareness”—that no single, clear meaning can be agreed upon. More precise definitions are needed to determine whether laypersons understand the term. Webster’s New World Dictionary defines ecology as follows:

- 1) The branch of biology that deals with the relationships between living organisms and their environment.
- 2) A branch of sociology concerned with the relationship between the distribution of human groups relative to material resources, and the resulting social and cultural patterns.

Maxwell (2003) explains that deep ecological awareness has a spiritual or religious dimension. When the concept of the human soul is understood as a mode of consciousness through which individuals feel a sense of belonging and connection with the cosmos as a whole, ecological consciousness reveals itself as fundamentally spiritual in nature. Equipping individuals with awareness reflected in ecological competence is of great importance. Kessler (2008) defines competence as the characteristics a person possesses that enable them to achieve success, referring to the integrative individual qualities that focus on solving real-world problems.

Sanghi (2007) draws a distinction between “competent” and “competence”: being competent refers to the skills and performance standards attained, while competence refers to the demonstrated behaviors. Ecological competence is built upon a person’s ecological awareness, which in turn plays a central role in fostering strong ecological competence. Recent literature reinforces this connection, emphasizing that assessing ecological competence requires evaluating not just theoretical knowledge, but actual sustainable behaviors and conative awareness (Crespo-Martín et al., 2026). Awareness, as the foundational behavior that motivates learning, directs competency assessment as a form of values-based evaluation. Competency assessment identifies the characteristics that determine whether an individual meets the desired standards—specifically, what it means to engage thoughtfully and responsibly with one’s environment (Pearson, 1987). Consequently, modern educational frameworks increasingly rely on multidimensional instruments to evaluate these foundational values and ensure they effectively translate into responsible pro-environmental actions (Fuentes Camacho et al., 2025).

Sengupta & Das (2010) note that “ecological awareness” has a broad connotation, encompassing not only knowledge about the environment, but also the attitudes, values, and skills required to address environmental problems. Furthermore, ecological awareness represents the first step toward developing the capacity for sustained responsible behavior. It is a systemic and integrative individual quality, characterized by the ability to address problems of varying complexity across diverse life situations and professional activities, based on established values, motivations, knowledge, educational experience, and personal needs.

Students at the elementary school level are in the process of building ecological awareness. Based on the Balinese concept of “Cucupu Manik” —the concept of “content and

container” – Bhuwana Alit (the microcosm) is the content, while Bhuwana Agung (the macrocosm) is the container (Sudira, 2011). Applied to ecological awareness, this concept frames students’ understanding and skills as the content, while school-based environmental activities serve as the forum.

The development of ecological awareness is important for students’ character formation; however, not all students develop such awareness easily. Students often participate in maintaining environmental cleanliness only when observed or instructed by teachers, and may otherwise ignore environmental upkeep, evidenced by littering, leaving classrooms dirty, and even damaging school garden plants. This may be partly due to insufficient modeling of cleanliness awareness at home, with poor habits subsequently carried over into the school environment.

Students’ ecological awareness is holistic, encompassing social skills alongside environmental and scientific dimensions. Understanding environmental awareness as a prerequisite for pro-environmental behavior underscores its behavioral importance (Kokkinen, 2013). Students’ ecological awareness can be observed through the behaviors reflected in their ecological competence. According to Muhaimin (2015) ecological skills include: (1) the ability to use and utilize resources wisely; (2) life skills in harmony with conservation and the environment; (3) environmental problem-solving skills; and (4) social skills related to environmental issues. Ecological awareness comprises four aspects: (1) knowledge related to the environment; (2) attitudes related to the environment; (3) skills related to the environment; and (4) participation in environmental activities.

If ecological awareness begins with the use of insight to solve environmental problems, then the primary responsibility falls on teachers to situate individual actions and their potential within both local and global perspectives. Failure to do so risks prioritizing action-based approaches in environmental education at the expense of developing students’ deeper action competencies (Jensen & Schnack, 1997).

Elementary school students are in a stage of cognitive, psychomotor, and affective development. The cultivation of ecological awareness is developmentally appropriate at the elementary school level; however, students at this stage are not yet capable of independently designing or initiating complex environmental practices. To effectively nurture ecological awareness, ecopedagogy-based learning is required – an approach that emphasizes contextual content development (Yunansah & Herlambang, 2017).

Measurement of environmental competence has grown alongside increasing human awareness of the importance of protecting the natural environment. Humans inherently differ in their perspectives toward the environment, and these views are generally shaped by cultural, ethnic, and geographical backgrounds. The ideal conditions for administering assessments are objectivity, transparency, fairness, and non-discrimination (Retnawati, 2008). This study therefore aims to detect differential item functioning (DIF) in the ecological awareness instrument across gender and grade groups.

Method

Sample

The sample in this study consisted of 623 elementary school students in Nusa Penida, comprising 329 boys and 294 girls. Sample selection was conducted using random sampling, with proportional representation across each village. The grade levels that received the research instrument ranged from Grade 4 to Grade 6. The number of students per grade was as follows: Grade 4 (n = 198), Grade 5 (n = 206), and Grade 6 (n = 219). Data collection was carried out from March 2019 to February 2020.

Instrument

The instrument used in this study was an ecological awareness instrument developed by the researcher based on the theoretical framework of Muhaimin (2015). The instrument

items were derived from four aspects of ecological awareness: (1) knowledge related to the environment; (2) attitudes related to the environment; (3) skills related to the environment; and (4) participation in environmental activities.

Data Analysis

This study employed Confirmatory Factor Analysis (CFA) to assess the fit of the theoretical construct model to the empirical data. CFA paid particular attention to the construct structure, comprising the aspects and items of the ecological awareness instrument, and was conducted using the R program (Wiradika, 2024) with the 'lavaan' package. Additionally, Cronbach's alpha reliability analysis was employed to evaluate the consistency of student responses.

Differential Item Functioning (DIF) analysis was conducted to identify item bias in the instrument. To detect DIF in polytomous data, several procedures were applied: (1) dimensionality testing using factor analysis; (2) estimation of focal group item parameters with reference groups; (3) calculation of the DIF index between groups; and (4) significance testing of the DIF index (Retnawati, 2014). Bias identification was performed across two subgroups: gender (female and male) and grade level (Grades 4, 5, and 6). DIF analysis was conducted using the R program with the 'lordif' package (Choi et al., 2011).

Result and Discussion

Instrument Testing

Reliability was assessed using Cronbach's Alpha in SPSS 22. The reliability coefficient obtained was 0.729, indicating that the ecological awareness instrument possesses good stability.

Ecological awareness scores were analyzed using Item Response Theory (IRT) with the Generalized Partial Credit Model (GPCM). Students' ecological awareness is represented through the theta (θ) parameter. With respect to gender, female students demonstrated a higher level of ecological awareness than male students.

This instrument was also used to identify ecological awareness levels among Grade 4, 5, and 6 elementary school students. IRT analysis revealed that Grade 4 students had the lowest level of ecological awareness, followed by Grade 5 students, while Grade 6 students demonstrated the highest level.

Table 1. Descriptive Statistics of Ecological Awareness by Sample Characteristics

Sample Characteristics	Mean of Theta	Theta Max	Theta Min	Theta	SD
Female	0.0724	2.25	-2.38		0.838
Male	-0.0655	2.10	-2.38		0.879
Grade 4	-0.1628	1.80	-2.38		0.869
Grade 5	0.0218	2.25	-2.38		0.909
Grade 6	0.1254	2.10	-1.50		0.789

One of the key assumptions for DIF identification is instrument unidimensionality. CFA was used to test the fit of the theoretical model to empirical data. Based on CFA results, almost all items yielded factor loadings > 0.3 ; item D1 had a factor loading < 0.3 , suggesting that all items except D1 adequately represented the ecological awareness construct.

Table 2. Factor Loading of the Ecological Awareness Instrument

Code	Item	A. Knowledge	B. Attitudes	C. Skills	D. Participation
A1	A clean and well-maintained natural environment will make a person feel comfortable	0.368			
A2	Environmental sustainability is a legacy for the sustainability of the next generation	0.387			
A3	Doing reforestation on dry land is a waste of time	0.436			
A4	Disposing of garbage in its place is part of an effort to protect the environment	0.462			
B1	Everyone must have a good attitude in behaving towards the environment		0.411		
B2	I don't care about the natural damage that occurs in the surrounding environment		0.629		
C1	Recycling various types of waste can be used in everyday life			0.506	
C2	Green waste can be used for compost			0.336	
D1	The use of materials or goods made from plastic must be reduced				0.256
D2	I have to save electricity by using only what I need				0.428
D3	Planting trees and reforestation in the community is very important				0.526
D4	Protecting the beach environment can				0.394

Code	Item	A. Knowledge	B. Attitudes	C. Skills	D. Participation
D5	be done by not damaging the corals and taking sand on the beach Excessive picking of school tree leaves to be used for play				0.422

The model fit test using second-order CFA analysis yielded RMSEA = 0.040 (RMSEA < 0.05), CFI = 0.931 (CFI > 0.90), and TLI = 0.909 (TLI > 0.90). These indices confirm a good model fit, indicating that the construct of the ecological awareness instrument is consistent with the empirical data.

Differential Item Functioning Analysis

Differences between groups can be observed in the frequency distribution of ecological awareness levels. Two or more populations are considered equivalent if they demonstrate the same distribution of ecological awareness levels. Group differences were examined at two levels: (1) the trait level, which concerns specific characteristics of population members, including gender and class; and (2) the frequency level, which relates to the relative frequency of these traits within each population.

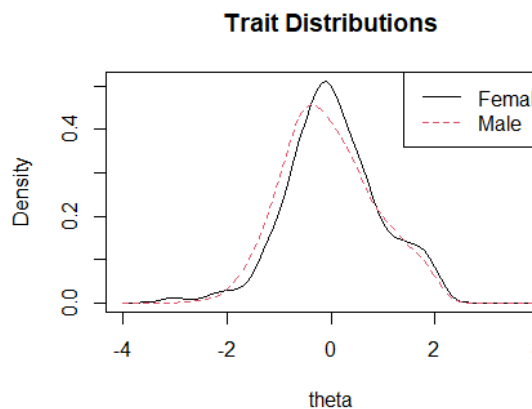


Figure 1. Trait Distribution of Female and Male Students

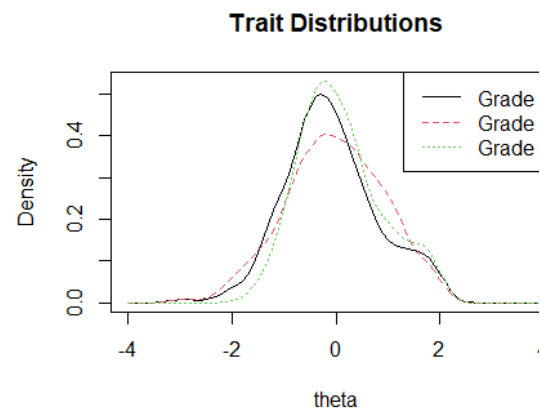


Figure 2. Trait Distribution of Grade 4, 5, and 6 Students

Figure 1 presents a histogram of the ecological awareness of elementary school students in Nusa Penida, comparing female students (solid line) and male students (dashed line) as measured by the ecological awareness scale (theta). Considerable distributional overlap was observed, though female students demonstrated higher levels of ecological awareness. Figure 2 presents the histogram comparing ecological awareness across grade levels: Grade 4 (solid line), Grade 5 (red dashed line), and Grade 6 (green dashed line). Overlapping distributions were also observed across grades, with Grade 6 having the highest ecological awareness, followed by Grade 5, and Grade 4 the lowest.

Test Characteristic Curves (TCCs) depict the expected total score for groups of items at each level of ecological competence (theta). Figure 3 shows the curve for all items (both with and without DIF), while Figure 4 shows the curve for the subset of items identified as containing DIF.

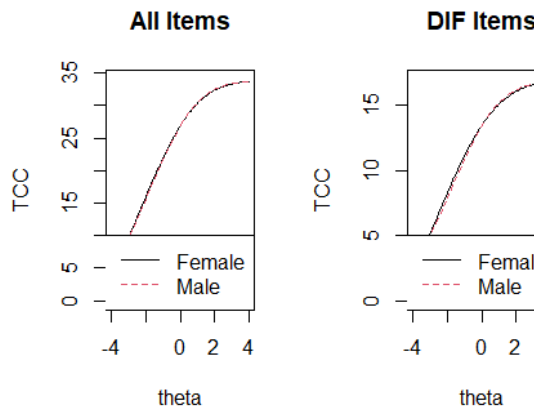


Figure 3. Impact of DIF Items on Gender Test Characteristic Curves

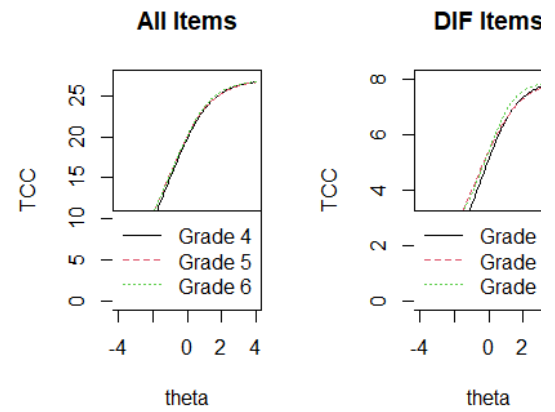


Figure 4. Impact of DIF Items on Grade Test Characteristic Curves

Figure 3 shows that at the overall test level, the expected total scores for male and female students differ minimally across theta levels. The non-intersecting curves with a visible gap indicate a persistent but consistent difference in expected scores between gender groups, suggesting uniform DIF.

In Figure 4, the TCCs exhibit minimal difference but intersect at a single point on the ability scale. This indicates non-uniform DIF at the overall test level. Non-uniform DIF occurs when item characteristic curves differ between groups and intersect, indicating that the direction of the advantage shifts at different ability levels.

To illustrate the difference between DIF-adjusted and unadjusted scores, individual-level DIF impact was computed. Figure 5 presents the DIF comparison between female students (triangles) and male students (circles), while Figure 6 presents the DIF comparison across Grade 4 (circles), Grade 5 (triangles), and Grade 6 (plus signs).

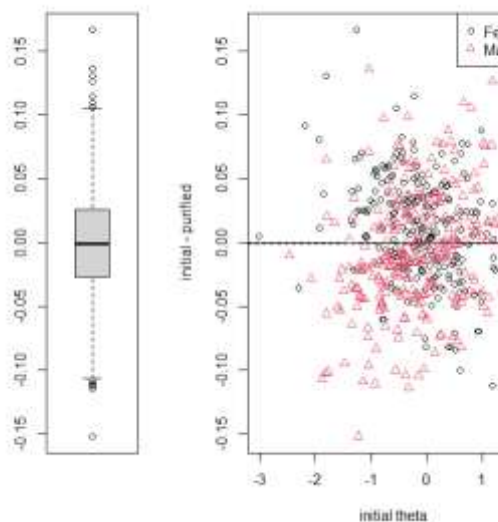


Figure 5. Gender Individual-Level DIF Impact

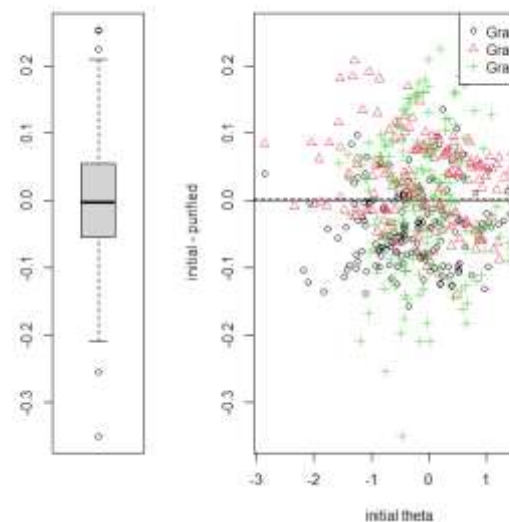


Figure 6. Grade Individual-Level DIF Impact

Figure 5 shows that individual-level DIF is quite pronounced across both genders. The theta values of male students tend to cluster in the negative range, while those of female

students cluster in the positive range, indicating that male students have lower ecological awareness than female students. Figure 6 shows that grade-level DIF is also notable. Grade 4 students tend to have lower ecological awareness, while Grades 5 and 6 show relatively higher awareness.

Table 3. Chi-Square Statistics for DIF Detection at Empirical Threshold ($\alpha = 0.05$)

Item	Gender			Grade		
	χ^2_{12}	χ^2_{13}	χ^2_{23}	χ^2_{12}	χ^2_{13}	χ^2_{23}
A1	0.380	0.281	0.183	0.316	0.000	0.000
A2	0.011	0.033	0.527	0.001	0.000	0.000
A3	0.439	0.668	0.648	0.002	0.001	0.071
A4	0.779	0.411	0.193	0.341	0.578	0.695
B1	0.901	0.793	0.503	0.025	0.000	0.000
B2	0.001	0.002	0.467	0.103	0.153	0.341
C1	0.224	0.471	0.867	0.234	0.261	0.308
C2	0.244	0.395	0.480	0.679	0.616	0.390
D1	0.003	0.011	0.617	0.159	0.280	0.500
D2	0.301	0.008	0.003	0.584	0.473	0.292
D3	0.302	0.582	0.891	0.103	0.303	0.860
D4	0.025	0.023	0.115	0.169	0.204	0.305
D5	0.006	0.011	0.226	0.004	0.005	0.141

The chi-square (χ^2) statistics in Table 3 were evaluated against the nominal threshold of 0.05. Results reveal that six items in the gender group exhibited DIF: items A2, B2, D1, D2, D4, and D5. In the grade group, five items were detected as biased: items A1, A2, A3, B1, and D5.

The results of this study indicate that, among gender groups, female students demonstrate a higher level of ecological awareness. This finding is consistent with prior research showing that female students tend to have greater environmental concerns than their male counterparts (Torkar & Bogner, 2019; Xiao & McCright, 2015). Items exhibiting gender bias are predominantly related to environmental participation. Women tend to hold broader awareness of environmental importance in general, while men tend to manifest environmental concern through more specific domains such as technology (Davidson & Freudenburg, 1996).

The items in this ecological awareness instrument were primarily designed to reflect general ecological behaviors. Notably, items in the skills dimension did not show item bias, which may be attributed to the environmental habituation practices at the research location, which are directed largely at contemporary environmental issues. Skills items focused on waste management were selected because this topic is commonly discussed in the community and is familiar to elementary school students.

In the grade group, a grade-based pattern emerged that corresponded with the level of ecological awareness among elementary school students. The uneven distribution of ecological awareness across grades is influenced by differences in environmental knowledge and active participation in environmental activities. Students' attention to environmental issues can be fostered through practices that engage them with real or potential environmental problems in their own area and beyond (Simsekli, 2015).

The key concept underlying ecological awareness is one's attitude toward the environment. Environmental attitudes must account for both cognitive and emotional dimensions. Attitudes toward the environment integrate affective and cognitive components (Pooley & O'Connor, 2000). Emotions are perhaps the most underappreciated and misunderstood aspect of environmental education (Martin, 2007). Ecological awareness should not be limited to critical thinking; it also requires attention to students' emotional responses to environmental issues explored in the classroom (Blatt, 2014). Before cross-group comparisons are made, DIF analysis should be conducted alongside empirical item characteristic curve representations to describe possible DIF patterns (Hidalgo et al., 2017). If any item in a test favors a particular group, the test is considered to contain bias or differential item functioning (Retnawati, 2013).

Conclusion

This study demonstrates that the ecological awareness instrument contains biased items. Item bias was most prevalent in the gender group. The occurrence of item bias is attributable to the inclusion of items that reflect general environmental practices, which may be interpreted differently across gender groups. Consistent with prior research, women demonstrate higher environmental awareness than men.

This phenomenon is strongly corroborated by recent international studies highlighting a significant "gender environmentalism gap," wherein female students consistently exhibit more robust pro-environmental behaviors, sustainable engagement, and generalized environmental attitudes across different educational settings (Crespo-Martín et al., 2026; Gyurián Nagy, 2025; Lopez-Bermudez et al., 2025; Scarci et al., 2025). Furthermore, the grade-based item bias detected in this study aligns with contemporary developmental research, which indicates that generational differences and age profiles significantly dictate how ecological concepts are conceptualized and translated into pro-environmental emotions and actions (Ágoston et al., 2024; Falcinelli et al., 2025). This finding underscores the importance of selecting instrument items that are equally interpretable by both male and female respondents.

The sample in this study comprised students from three upper grade levels of elementary school (Grades 4, 5, and 6). This selection was intended to assess the ecological awareness of students who had already received environmental content in the curriculum. The findings also revealed grade-based item bias, with the most affected dimension being environmental knowledge. Ecological awareness, as a construct combining knowledge and affective components, requires careful instrument design when measuring students across different grade levels, given their differing levels of cognitive and affective development.

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