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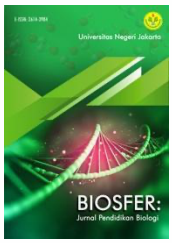

# Assessing students' sustainability consciousness in biology learning: empirical evidence through rasch analysis

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**ABSTRACT**

Sustainability consciousness acts as a compass in making considerations, behaving, and acting with attention to sustainability aspects. This research aims to determine how the sustainability consciousness of high school students is assessed using the Sustainability Consciousness Questionnaire (SCQ), which has been adapted and tailored to the research context. The collected data were analyzed using comprehensive Rasch modelling to measure latent variables. The Rasch analysis was conducted using the Winsteps application, focusing on validity, reliability, student sustainability consciousness, and Differential Item Functioning (DIF). Based on the Rasch analysis, it was found that the sustainability consciousness of the students was relatively good and varied across three analyzed dimensions: sustainability knowingness, sustainability attitudes, and sustainability behavior. The DIF analysis revealed that there were two items out of a total of 27 that fell into the DIF category. This indicates that there are differences in responses shown by male and female students. These findings support previous research regarding how attitudes toward sustainability differ based on gender. Furthermore, the topics explored in biology learning are highly relevant to the majority of issues that are central to sustainability concerns. Therefore, through biology education, students' knowledge, attitudes, and behaviors can be nurtured and developed. In this way, the knowledge they acquire can be transformed into concrete actions. Moreover, this study contributes to empirical research on sustainability consciousness demonstrated by high school students.

## INTRODUCTION

Sustainability consciousness in education to achieve the Sustainable Development Goals (SDGs). Goal 4.7 of the SDGs emphasizes the importance of education that promotes sustainable development (Kioupi & Voulvoulis, 2019). Sustainability consciousness refers to the experience or awareness of sustainability phenomena. This concept encompasses perceptions, awareness, and individual engagement in sustainability phenomena, involving elements such as held beliefs, feelings toward sustainability issues, and concrete actions taken to support sustainability (Gericke et al., 2019).

Sustainability consciousness is a concept regarding awareness that integrates the three dimensions of sustainable development: social, environmental, and economic. The sustainability consciousness across these three dimensions consists of aspects of knowledge (knowingness), attitudes, and behaviors related to sustainability, which serve as indicators of sustainability consciousness within each dimension (Olsson et al., 2015). Consciousness is a concept dependent on several individual characteristics or factors. Sustainability consciousness is a multidimensional concept that encompasses cognitive (knowledge), affective (attitudes), and conative (behavior) aspects related to sustainability in three main domains: environment, social, and economic (Gericke et al., 2019). The knowledge aspect (knowingness) relates to the learners' understanding of fundamental principles underlying sustainable development. The knowledge aspect consists of cognitive components based on knowledge and affective components based on perception (Berglund et al., 2014).

Attitudes and behaviors are components of the affective domain related to emotions (Berglund et al., 2014). Attitude can be defined as a lasting positive or negative feeling towards an issue, person, or object (Kollmuss & Agyeman, 2002). The attitude aspect refers to individuals' positive and negative emotions in response to sustainable development. Attitude measurement is broader than the measurement of behavioral aspects (Saleem & Dare, 2023). However, attitude alone is not sufficient to predict individuals' behavior, as many factors can shape human behavior (Berglund et al., 2020). The behavior aspect refers to individuals' tendencies to support or oppose issues related to sustainable development (Gericke et al., 2019). Behavior can also be understood as a cultural expression that exists within a community according to its history, traditions, and context (Berglund et al., 2020). Environmentally friendly behaviors can help reduce environmental impacts and play a role in mitigating environmental change (Truelove & Gillis, 2018).

Education plays a central role in fostering sustainability consciousness (UNESCO, 2017). Education for Sustainable Development (ESD) is designed to equip learners with critical thinking skills (Sobari, 2022), problem-solving abilities (González-Pérez & Ramírez-Montoya, 2022), and sustainability-based decision-making skills (Sihombing et al., 2024). There are three main approaches that can be applied to support the role of education in enhancing sustainability consciousness. The educational approaches that can be undertaken include curriculum integration (Fuertes-Camacho et al., 2019; Kalsoom et al., 2017; Tasdemir & Gazo, 2020), innovative learning methods (Saraiva et al., 2024; Tejedor et al., 2019), and contextual factors such as culture and educational policy (Menon & Suresh, 2020).

Integrating sustainability aspects into school and university curricula is an important step in building sustainability consciousness. One way to do this is by adding explicit material on environmental, social, and economic sustainability to biology learning topics. An interdisciplinary approach can complexly view issues not in a linear manner but in a multidisciplinary way. At several universities, special courses such as sustainability studies or green economics have been introduced to provide students with an in-depth understanding of sustainability. In primary and secondary schools, eco-school programs are introduced to teach students environmentally friendly practices (Brito et al., 2018).

The application of innovative learning methods can enhance students' sustainability consciousness, especially in biology learning. In schools, project-based learning and problem-based learning that apply sustainability projects and real-life problems can serve as innovative learning methods (Pan et al., 2023). The zero waste school program, where students participate in recycling and waste management, can be a means to increase sustainability consciousness (Kaniwati & Sriyati, 2021). A systems thinking approach to understanding the complex relationships between various aspects of sustainability helps students comprehend how local actions have global impacts (Demssie et al., 2023). Direct activities in the field provide opportunities for students to engage directly in sustainability actions through experiential learning (Ely, 2018).

Students are also part of community life; therefore, sustainability consciousness is influenced not only by formal education but also by contextual factors. Cultural influences such as community cooperation can become local wisdom and traditions that promote social and environmental responsibility (Berglund et al., 2019). Educational policies in shaping sustainability consciousness can be realized through ESD programs in schools that adhere to global sustainability education standards (Al-Nuaimi & Al-Ghamdi, 2022). Previous research has examined how the application of the consciousness concept from an environmental perspective works. Sánchez & Lafuente (2010) explain that environmental consciousness is a psychological or attitudinal dimension that underpins pro-environmental behavior; thus, its operationalization includes several dimensions: affective, cognitive, dispositional, and active. The complexity of sustainability consciousness dimensions with different characteristics poses challenges in measuring students' sustainability consciousness. This research employs Rasch analysis to obtain more accurate and reliable measurements in assessing students' sustainability consciousness. The significance of this research lies in providing empirical evidence regarding the sustainability consciousness of secondary school students in Indonesia.

## METHODS

### Research design

The research design employed in this study is descriptive research with a quantitative approach, in order to gain a depiction of the high school students' sustainability consciousness through the measurement using the Sustainability Consciousness Questionnaire (SCQ) instrument.

### Participants

This study involved students from a senior high school in West Sumatera, selected through non-random sampling due to practical constraints and limited resources. The participants consist of 48 male students and 45 female students in the 10$^{th}$ grade.

### Instrument

The instrument used to measure sustainability consciousness is the Sustainability Consciousness Questionnaire (SCQ), which is adapted from (Gericke et al., 2019) with language translation and wording adjustments to ensure comprehension by the students. This instrument employs a five-point Likert scale, consisting of three dimensions: the environmental dimension, the social dimension, and the economic dimension.

### Procedure

This research conducted in three main stages, particularly preparation, implementation, and findings report, as can be seen in Figure 1. In the preparation stage, a comprehensive literature review was conducted to identify and select the appropriate instrument. Since the instrument for sustainability consciousness had already been developed and published by Gericke et al. (2019), it was adopted for use in this study. The instrument was translated and linguistically adjusted to ensure clarity and contextual relevance before being distributed to students via Google Forms. During the implementation stage, the instrument was administered to students on different days, aligned with their respective biology class schedules. In the final stage, the collected data were compiled and analyzed using Rasch model to examine the responses given by the students.

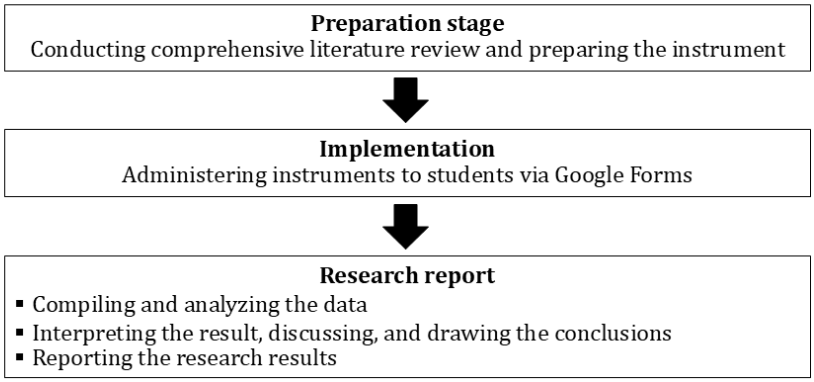


**Figure 1**. The research procedure

**Data Analysis Techniques**

Data were collected and compiled into Microsoft Excel, which was subsequently imported and analyzed using Rasch analysis through Winstep version 5.8.4. The validity of the instrument measured includes content validity through validity fit, which can be determined through two indices: Infit MNSQ (mean-square) and Outfit MNSQ (mean-square). Construct validity was assessed through unidimensionality testing. Reliability and separation values were also measured. The reliability measured includes person reliability and item reliability, as well as separation. Through Rasch analysis, it is also possible to determine differences in students' sustainability consciousness grouped by gender. Differential Item Functioning (DIF) analysis, which can be conducted using Winsteps, provides information on whether questionnaire items function differently based on gender. The codes used to represent students are M for male students and F for female students.

## RESULTS AND DISCUSSION

There are two validity tests conducted on the instrument: content validity and construct validity. Content validity can be determined through fit validity (Chan et al., 2021) paying attention to outfit MNSQ data (Boone & Staver, 2020). The obtained outfit MNSQ value is 1.10, indicating that all items fit the model because it falls within the range of 0.5 to 1.5 (Boone et al., 2014). Subsequently, construct validity can be determined from the unidimensionality test. High item performance can be identified from the raw variance value obtained, which exceeds 20%, at 34.3%, thus meeting the unidimensionality criteria (Sumintono & Widhiarso, 2014). Therefore, all items can be assessed as productive in measuring students' sustainability consciousness, which can be seen in Table 1.

**Table 1**
Summary of Rasch parameters for quantitative study instrument tests

| Psychometrics attribute | Results |
|---|---|
| Number of items | 27.00 |
| Mean | |
| Item outfit MNSQ | 1.10 |
| Item Infit MNSQ | 1.00 |
| Person outfit MNSQ | 1.10 |
| Person Infit MNSQ | 1.18 |
| Cronbach's Alpha | 0.92 |
| Reliability | |
| Item reliability | 0.90 |
| Person reliability | 0.91 |
| Unidimensionality | |
| Raw variance by measures | 34.30% |

A high level of interaction between respondents and items can be determined from the Cronbach Alpha coefficient value obtained from the Rasch Model calculation, which is 0.92 as revealed in Table 1. This value reflects the interaction between 93 respondents and 27 items, which falls into the "very good" (Sumintono & Widhiarso, 2014). The item reliability obtained shows that all items are reliable with a value of 0.90, which falls into the "excellent" category. Furthermore, the person reliability obtained is 0.91, which also falls into the "excellent" category. This indicates the consistency of respondents' answers (Sumintono & Widhiarso, 2015), as presented in Table 1.

**Students' Sustainability Consciousness**

Rasch modelling is suitable for measuring latent traits and has become a primary latent measurement approach in various (George Engelhard Jr. & Stefanie Wind, 2018; Massof, 2011; Sumintono, 2018). It provides comprehensive information when used to measure students' understanding at various levels of learning complexity (Herrmann-Abell et al., 2023). Therefore, in this study, the Rasch analysis was conducted to determine the level of students' sustainability consciousness, represented by the interaction between the questionnaire items and respondents, as presented in the Wright map(Bond et al., 2021). Three constructs or dimensions were observed in the Rasch analysis according to the Sustainability Consciousness Questionnaire (SCQ) developed by oleh

Gericke et al., (2019)). Table 2 shows the constructs and items analyzed using Rasch modeling. These dimensions include sustainability knowingness, sustainability attitudes, and sustainability behavior. Each dimension is reviewed from the sustainability aspects of environmental, social, and economic factors.

**Table 2**
Constructs of the quantitative study instrument

| Construct/dimension | Item |
|---|---|
| Sustainability knowingness | SC1, SC2, SC3, SC4, SC5, SC6, SC7, SC8, SC9 |
| Sustainability attitudes | SC10, SC11, SC12, SC13, SC14, SC15, SC16, SC17, SC18 |
| Sustainability behaviour | SC19, SC20, SC21, SC22, SC23, SC24, SC25, SC26, SC27 |

In the Wright map shown in Figure 2, it can be observed that the questionnaire items that received higher agreement from students are positioned higher or more positively on the logit scale(Boone et al., 2014). The majority of items in the sustainability knowingness dimension were easier for students to agree with, as seen from the negative logit values for items SC2 (Preserving biodiversity is necessary for sustainable development), SC3 (For sustainable development, communities need to be educated on how to protect themselves from natural disasters), SC4 (A culture where conflicts are resolved peacefully through discussion is necessary for sustainable development), SC5 (Respecting human rights is necessary for sustainable development), and SC6 (To achieve sustainable development, everyone in the world must have access to quality education). These findings indicate that students have a good understanding of the environmental and social aspects of sustainability consciousness . It can be understood that students are aware of the importance of biodiversity conservation efforts, which is an essential variable for human life (Niesenbaum, 2019; Sekhar et al., 2024) and education on disaster resilience, which can help mitigate the impacts of various forms of disasters (Rose, 2011). Both aspects fall under the environmental category. Students also understand the urgency of respecting human rights, peaceful resolution of conflicts, and equitable access to quality education, which are the social aspects of sustainability. This understanding can serve as a starting point for supporting the realization of sustainability ideals (Sekhar et al., 2024; Zeegers & Clark, 2014).

There are items in two aspects of the sustainability knowingness dimension that are relatively difficult for students to agree with compared to other items, indicated by positive logits for item SC1 (Conserving water consumption is necessary for sustainable development) and SC9 (Eradicating poverty in the world is necessary for sustainable development), which fall under the environmental and economic aspects of sustainability. Students' difficulty in agreeing indicates their understanding and concern regarding issues of water conservation and community welfare. A lack of understanding and motivation to engage in water conservation may underlie this (M & Shaji, 2021; Sasa et al., 2024; Valenzuela-Morales et al., 2022; Wise et al., 2021). Community welfare is a complex issue that requires comprehensive knowledge to understand, which may explain the difficulty in agreeing with this item (Zimmerman & Weible, 2017).

Meanwhile, in the economic aspect of the sustainability knowingness dimension, students tended to remain neutral on items SC7 (Sustainable development requires companies to act responsibly towards their employees, customers, and suppliers) and SC8 (Sustainable development requires a fair distribution of goods and services among people in the world). Students' neutrality towards these statements may indicate that these issues have not received particular attention from students, possibly due to a lack of exposure to these issues in their daily lives (Filho et al., 2024; Sierra & Suárez-Collado, 2021), leading students to be less decisive regarding the statements presented.

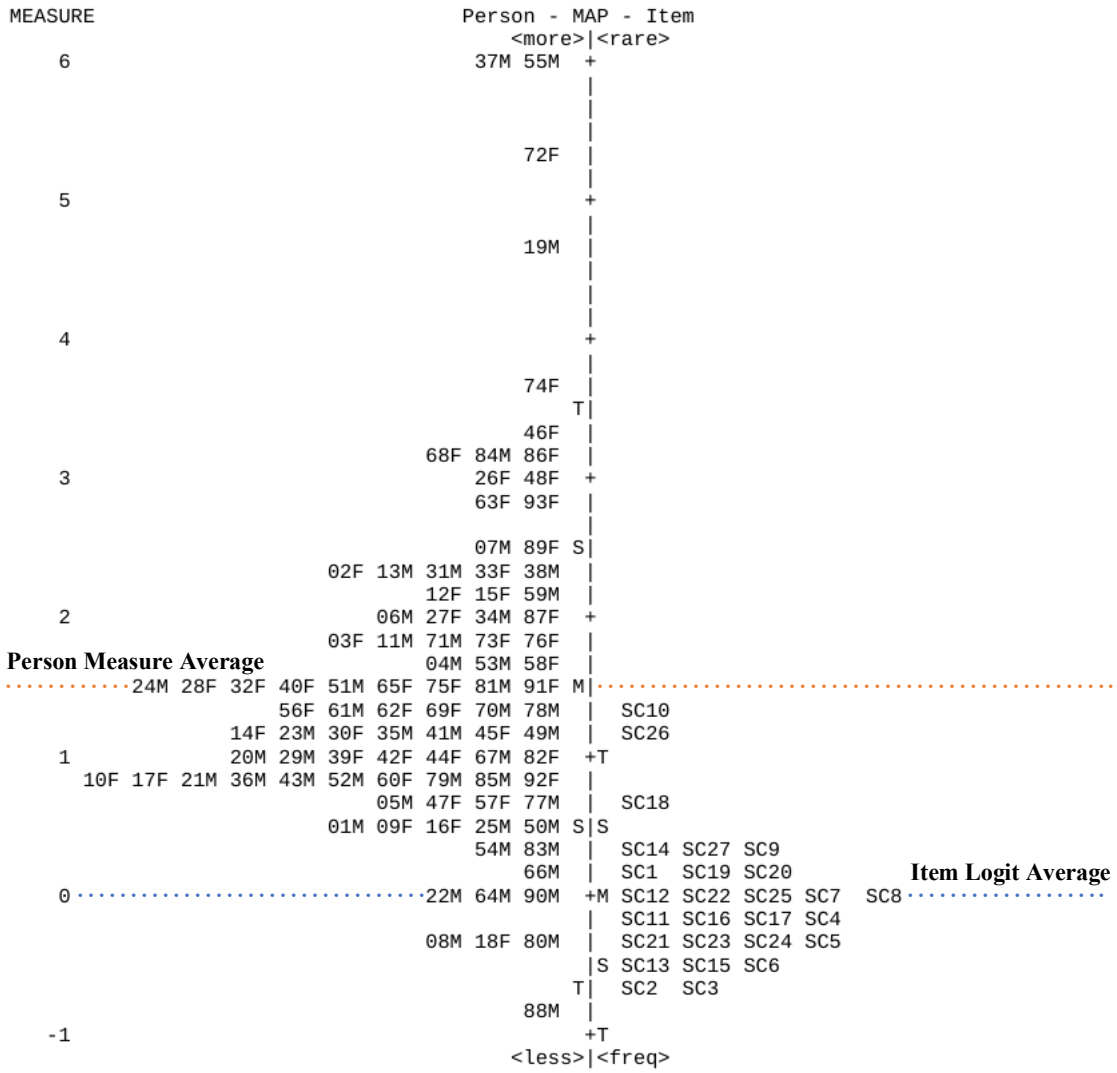


**Figure 2**. Wright Map

As with the previous dimension, in the dimension of sustainability attitudes, more than half of the statements were more easily agreed upon by students, namely item SC11 (I think we need stricter laws and regulations to protect the environment), SC13 (I believe everyone should be given the opportunity to acquire knowledge, values, and skills necessary for sustainable living), SC15 (I think women and men around the world should be given equal opportunities for education and employment), SC16 (In my opinion, companies have a responsibility to reduce the use of packaging and single-use items), and SC17 (I believe it is important to reduce poverty). This indicates that students have a positive attitude towards environmental protection efforts as well as gender equality in access to education and employment opportunities (Kuteesa et al., 2024; Shafiei & Maleksaeidi, 2020). Students also show positive concern regarding the welfare of grassroots economic actors and how policies in the industrial sector can support environmental sustainability. This reflects students' understanding of the industrial sector's role in creating a more sustainable economic system (Grover & Chhabra, 2024).

In item SC12 (I think it is important to take action on issues related to climate change), students tend to show a neutral attitude. This is interesting given that climate change issues are currently being promoted. This is due to the increasingly evident impacts of the climate crisis felt by humanity. The ambivalence shown by students may be due to a lack of exposure to climate issues found in the classroom or in daily life (Almansa-Martínez et al., 2024; Chang & Pascua, 2017; Hess & Maki, 2019).

Meanwhile, there are three items from three different aspects of the sustainability attitudes dimension that students tend to find hard to agree with, namely item SC10 (I think using natural resources more than we need will not threaten human health and well-being in the future), SC14 (I believe we who live now must ensure that future generations enjoy a quality of life equal to ours today), and SC18 (I think companies in wealthy countries should provide the same conditions to employees in

poorer countries as in wealthy countries). These three items represent the environmental, social, and economic aspects of the sustainability attitudes dimension, respectively. This indicates that the majority of students have a very positive attitude in considering the impact that decisions made today will have in the future (Aznar-Díaz et al., 2019; Imran et al., 2024). However, students tend to find it difficult to agree on efforts to ensure that future generations have the same quality of life as the present. This can be viewed as a form of concern among students given the ongoing massive environmental degradation.

Unlike the previous two dimensions, the majority of items in the sustainability behavior dimension tend to be harder for students to agree with, as indicated by positive logit values on the logit scale. This is found in item SC19 (I recycle as much as I can), SC20 (I always separate food waste before throwing trash when there is an opportunity), SC26 (I often buy second-hand goods online or at stores), and SC27 (I avoid buying from companies with a poor reputation for caring for employees and the environment). These four items relate to environmental and economic aspects. The two items from the economic aspect of the sustainability behavior dimension tend to be harder to agree on than the two items in the environmental aspect. This indicates that sustainability behavior in the economic aspect has not been optimally realized by students at the individual level (Alsaati et al., 2020). Recycling behavior and waste separation require support in terms of facilities and strict regulations within the system, so that environmental conservation efforts receive serious support to be realized (Oyekale, 2018; Stoeva & Alriksson, 2017; Xiao et al., 2021).

Furthermore, the understanding and positive attitude towards environmental aspects have not escalated into behaviors and habits implemented by students. This area can be further explored in subsequent research. The items that were easier for students to agree with are item SC21 (I have changed my personal lifestyle to reduce waste (for example, throwing away less food or not wasting materials)), SC23 (I support aid organizations or environmental groups), and SC24 (I show the same respect to men and women, boys and girls). These three items represent environmental and social aspects of the sustainability behavior dimension. Although the majority of items from the behavior dimension were difficult for students to agree with, students have already shown positive behavior in terms of reducing waste generated from their daily lifestyles (Alattar & Morse, 2021). Students also exhibit positive behavior in providing support for environmental conservation efforts and showing respect to others regardless of gender and age.

In the sustainability behavior dimension, students tend to be neutral towards the statements of behavior on two items from the social and economic aspects, namely item SC22 (When I use a computer or phone to chat, send messages, play games, and so on, I always treat others with respect as I do in real life) and item SC25 (I do things that help poor people). The neutrality shown by students in these social and economic aspects may stem from the fact that the principles of respect and concern for others have not yet been optimally realized in the form of behaviors and actions in everyday life (Maurer & Bogner, 2019).

Planning for a sustainable future requires consideration of a number of concerns, including biodiversity, climate change, the sustainable use of natural resources, health, cultural diversity and heritage, and global well-being (Jeronen et al., 2017). Most of these topics are learned in biology learning. Socioscientific issues that are relevant to sustainability and learned in the biology learning process, allow students to be able to apply the concepts that have been obtained to problems found in the real world (Jackson et al., 2023).

Therefore, through studying sustainability issues in biology classes, elements of sustainability consciousness can be formed in terms of knowledge, attitude, and behavior. Although students' awareness of sustainability was relatively good in this study, in the behavioral dimension, students showed difficulty in agreeing with the statements presented in the questionnaire. Thus, it can be understood that the behavioral aspect of the students is not as strong as their knowledge and attitudes. This indicates a space that needs to be filled by biology learning, where the understanding possessed by students can be further developed and trained until it is manifested in the form of real behavior. This can be realized through biology learning topics that are relevant to sustainability issues.

**DIF based on students' gender**

Based on the DIF analysis conducted, it was found that there are significant differences in responses to item statements based on students' gender. This was indicated by the DIF values obtained. There are two items with a probability value of less than 5% (Sumintono & Widhiarso, 2015), as can be seen in Table 3, and the data visualization of DIF can be seen in Figure 3.

**Table 3**
Differential Item Functioning of students' sustainability consciousness

| Item | DIF | | DIF Contrast | t | Prob |
|---|---|---|---|---|---|
| | Male (M) | Female (F) | | | |
| SC1 | 0.49 | -0.51 | -1.0 | -3.25 | 0.0017 |
| SC15 | -0.23 | -0.93 | -0.70 | -2.03 | 0.0460 |

Item SC1 (Reducing water consumption is necessary for sustainable development) and item SC15 (I believe that women and men around the world should be given equal opportunities for education and employment) display a gender bias among students, whereby both items are more difficult for male students to agree with compared to female students. This can be seen in the DIF measure, which is higher for male students than for female students. This means that female students are more likely to agree with statements related to reducing water consumption as a form of support for sustainable development and are more likely to agree with equal access to education and job opportunities. This indicates that female students tend to have a more positive attitude towards sustainability compared to male students (Bucht et al., 2024; Cifuentes-Faura & Noguera-Méndez, 2023).

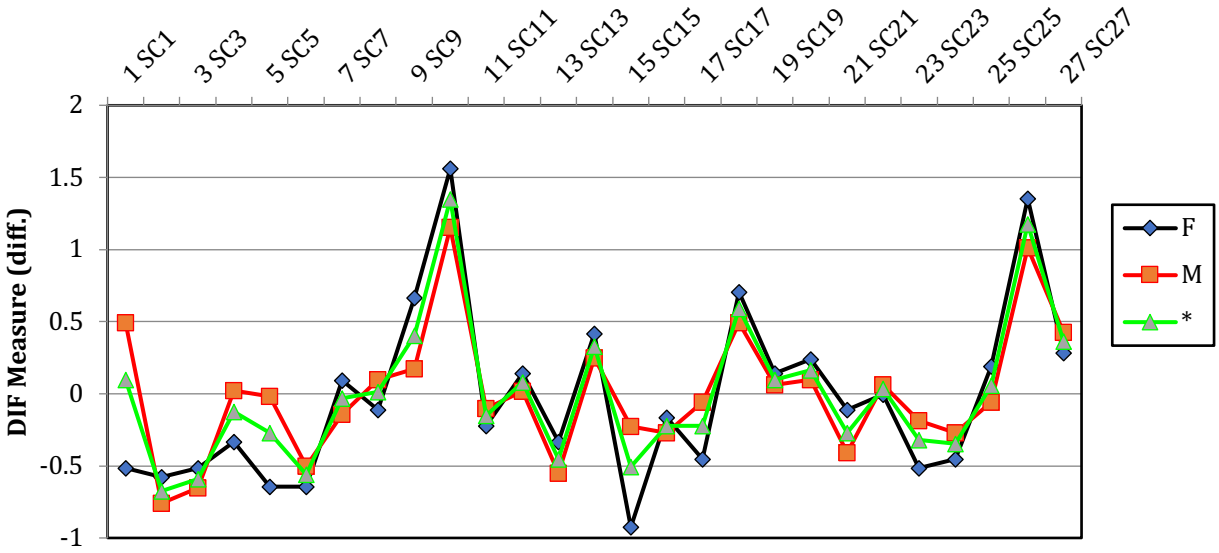


**Figure 3**. Data Visualization of DIF

Further exploration is necessary to identify the factors that cause significant differences in attitudes towards sustainability between male and female students, including issues related to equitable access to education, as education is the foundation of human civilization. The differences in understanding and attitudes demonstrated by male and female students regarding water conservation and gender equality in education and employment can be influenced by the social and cultural situations experienced by the students. The experiences that students have shape the perspectives they hold today.

## CONCLUSION

The Rasch analysis in this study provides insights into students' sustainability consciousness, which is rated relatively good and varies, examined from the dimensions of knowledge, attitude, and behavior in each aspect of sustainability, namely, environmental, social, and economic aspects. There are two gender-biased statements related to water conservation and equitable access to education and employment. These findings support previous research related to how differences in attitudes toward sustainability are shown by different genders. Furthermore, biology education should be designed to include contextual and application-oriented learning activities, ensuring that students' knowledge does not remain at the level of understanding alone but is gradually transformed into meaningful actions and behaviors. Overall, this article offers insights into the sustainability consciousness demonstrated by high school students, and these results can contribute to empirical studies on sustainability consciousness.

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