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Development of a Wetland-Oriented Global Warming Conceptual Understanding Test Using Rasch Model

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Abstract: One of the main issues in Sustainable Development Goal (SDG) 13 is global warming, which demands increased climate literacy through science education. However, previous research has shown the limited availability of valid and contextual assessment instruments to measure the understanding of global warming concepts oriented towards wetland characteristics. This study aims to develop and analyze a wetland-oriented global warming concept understanding test using the Rasch model. This research and development uses a 4D model consisting of the Define, Design, Develop, and Disseminate stages. The instrument, which has been validated by experts and tested on a limited basis, was then empirically tested on 254 10th-grade high school students in Banjarmasin City. The analysis results show that the test validity is in the good category, while the test reliability is in the good category with a Cronbach's Alpha value of 0.87. The Wright map item shows the distribution of item difficulty levels divided into four groups based on a mean of 0.00 and a standard deviation of 0.95. The test information function is normally distributed. The Outfit MNSQ, Outfit ZSTD, PT Measure Correlation, and item characteristic curves showed that all items fit the model. These findings confirm that the developed instrument is suitable for measuring understanding of global warming concepts fairly and contextually. This study demonstrates that integrating wetland contexts into assessments can strengthen the relevance of physics education to climate change issues and support the development of sustainable climate literacy at the secondary school level.

Keywords: Conceptual understanding; Global warming; Rasch; Test; Wetland

Introduction

Global warming is a global issue with significant impacts on environmental, social, and economic sustainability. Global warming is the long-term warming of the Earth's atmosphere driven by anthropogenic activities, such as burning fossil fuels, which increase greenhouse gas concentrations that trap heat in the atmosphere (Douville et al., 2021; Kumar et al., 2023; Alakbarov & Hajiyeva, 2025; Espinola & Roleda, 2025). Global temperature increases driven by human activities have reached alarming levels and are increasing the frequency of extreme climate events, sea level rise, and ecosystem degradation (Habibullah et al., 2022; Kumar et al., 2023; Yohana & Ojija, 2025). Global warming is part of Sustainable Development Goals (SDGs) 13, which is related to Climate Action (Yohana & Ojija, 2025). SDG 13 emphasizes the importance of education and increasing climate literacy as the foundation for climate change mitigation and adaptation (Cohen et al., 2021; Yohana & Ojija, 2025; Yolanda & Pribadi, 2025). Global warming demands climate literacy in learning, one of which is in physics learning (Ali et al., 2021). Physics learning has a crucial role in constructing a correct and sustainable conceptual understanding of global warming. The concept of global warming in physics relates to energy, radiation, temperature, and heat, the Earth and space, and human interaction with the environment (Toffaletti et al., 2022). However, various studies show that students' conceptual understanding of global warming remains low, and there are misconceptions, especially regarding

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the greenhouse effect and the relationship between human activities and climate change (Toffaletti et al., 2022). A good understanding of the concept is necessary to prevent students from developing misconceptions (Dewi & Suhandi, 2017; Nehru et al., 2020). Students' conceptual understanding can be known using instruments (Saepuzaman & Karim, 2016; Istiyono et al., 2023). However, existing learning assessment tools are insufficient if they only measure basic cognitive achievement; they must also be able to uncover the structure of conceptual understanding within students' mental models in depth. Therefore, these assessment tools must be powerful and holistic in uncovering conceptual understanding related to global warming.

The urgency of the global warming issue is increasingly contextual when linked to the context of Banjarmasin as a wetland ecosystem area in Indonesia (Lasiani & Setiono, 2025). Banjarmasin is dominated by swamp and tidal river ecosystems, which make it very susceptible to the impacts of climate change, such as tidal flooding, extreme waterlogging, extreme weather changes, and environmental degradation. However, wetlands serve a crucial ecological function in sequestering carbon and regulating the microclimate (Adade Williams et al., 2020; Akhtar et al., 2021; Karmakar et al., 2023; Yohana & Ojija, 2025). These conditions make wetlands a highly relevant authentic context for learning about global warming (Lasiani & Setiono, 2025). However, science learning in wetland areas has not been widely integrated with the characteristics of these environments (Lusiana et al., 2025). As a result, students' conceptual understanding is incomplete and disconnected from the realities of their surroundings. This underscores the need for assessment instruments that not only measure general understanding of global warming concepts but also focus on the wetland context.

Understanding concepts is one of the important and fundamental achievements in learning physics (Fitri et al., 2021; Huda et al., 2017), which determines success in science learning (Dewi & Suhandi, 2017; Nehru et al., 2020). Conceptual understanding is relational knowledge about the key concepts of a domain, along with the relationships between concepts and the differences between concepts, including understanding the relationships between real phenomena and abstract principles (Nisyah et al., 2020). This requires students to be able to interpret, exemplify, explain, compare, and classify a concept (Fernandez, 2017; Herimanto et al., 2018; Fitri et al., 2021; Ole & Gallos, 2023). Interpretation refers to students' ability to translate the information they obtain. Exemplifying refers to providing examples based on a concept. Explaining requires students to explain the cause-and-effect of a phenomenon. Comparing involves determining the relationships between observed phenomena. Classifying, on the other hand, refers to grouping the characteristics of a phenomenon based on the appropriate concept. Understanding concepts is the foundation of the cognitive abilities above it, namely the ability to apply, analyse, evaluate, and create (Anderson & Krathwohl, 2001). Furthermore, conceptual understanding is the basis for various skills in the 21st century, such as critical, creative, communicative, and collaborative thinking skills (Fitri et al., 2021; Nehru et al., 2020; Dessie et al., 2023). Therefore, a holistic and in-depth understanding of a concept is essential so that students can construct knowledge at a higher level (Riaz et al., 2019; Dessie et al., 2023). A low conceptual understanding of physics can lead to misinterpretation of scientific concepts, resulting in misconceptions and decision-making that is not based on the correct concepts (Hariyono et al., 2023). Students' conceptual understanding of physics processes shapes how they think about the phenomena around them (Balta et al., 2022) because physics has a close relationship with facts, concepts, principles, laws, and processes (Oktalia et al., 2017; Nehru et al., 2020).

Developing conceptual understanding tests requires a psychometrically robust measurement approach. The widely used Classical Test Theory (CTT) (Mešić et al., 2019) has fundamental limitations compared to IRT (Hambleton et al., 1991), such as the dependence of item parameters on the sample and limited diagnostic information at the item level (Bond, 2015; Bozdağ & Türkoğuz, 2021; Balta et al., 2022). These limitations have serious implications when the instrument is used to measure complex and multidimensional constructs (Bozdağ & Türkoğuz, 2021), such as understanding the concept of global warming. As an alternative solution, the Rasch Model is seen as having significant advantages through the principle of objective measurement, in which student ability and the difficulty of test items are mapped onto a logit scale that is invariant across samples and instruments (Boone et al., 2014; Boone & Noltemeyer, 2017; Hamdu et al., 2023; Balta et al., 2022). In addition, Rasch analysis allows for the identification of misfit items, testing of unidimensionality, and detection of item bias through Differential Item Functioning (Liu & Boone, 2006; Liu, 2010; Sumintono & Widhiarso, 2015). Several studies have revealed that Rasch-based test instruments have stronger construct validity and reliability than CTT-based instruments, especially in measuring conceptual understanding (Krathwohl, 2002; Balta et al., 2022; Istiyono et al., 2023). However, previous research on the development of conceptual understanding tests (Putranta & Supahar, 2019; Silaban & Istiyono, 2024; Andriani et al., 2023; Istiyono et al., 2023) has not been directly oriented to the wetland context. The Rasch model has been used in conceptual understanding studies (Bozdağ & Türkoğuz, 2021; Hamdu et al., 2023; Mešić et al., 2019), but those related to global warming remain rare, especially in the context of wetland ecosystems. Therefore, the development of a wetland-oriented conceptual understanding test using the Rasch model is deemed necessary.

This research is urgent and has an impact, both theoretically and practically. This research enriches the study of the contextual and sustainable evaluation of physics learning by integrating a wetland context and a modern Rasch-based measurement approach into a holistic conceptual understanding test instrument. In addition, the developed conceptual understanding test instrument is expected to be a powerful, valid, and reliable assessment tool. Furthermore, this research encourages direct contributions to climate change education as part of the implementation of sustainability education in the context of SDG 13.

Method

Research Design

This research is included in the research and development (R&D) type to develop a global warming concept understanding test oriented towards wetland environments. This study uses the 4D models by Thiagarajan, Semmel, and Semmel, which consist of the Define, Design, Develop, and Disseminate stages (Thiagarajan et al., 1974). In the Define stage, researchers analysed the curriculum and expected learning outcomes for high school students in phase E. In addition, the researcher conducted a preliminary study to assess field needs. In this case, the researcher conducted interviews with the four physics teachers at several high schools in Banjarmasin. In the Design stage, the researcher designed the test instrument to be developed. The researcher created a test item matrix and a question grid and determined the question assets. The researcher began constructing questions in the Develop stage based on what had been determined in the previous stage. The conceptual understanding test developed in this study is in a multiple-choice format with five answer options. Researchers conducted a pilot test of the developed test instrument. Afterwards, they analysed the test's characteristics based on empirical testing. In the Disseminate stage, researchers disseminated the final product, which had been tested for quality, to physics teachers in Banjarmasin, South Kalimantan.

Sample and Data Collection

This research on the development of a global warming conceptual understanding test instrument oriented towards wetlands was conducted in Banjarmasin City, South Kalimantan. South Kalimantan is a province in Indonesia characterized by wetlands. Almost all of this area is composed of peat. Banjarmasin is nicknamed the city of a thousand rivers. The sample of this study was 254 tenth-grade high school students in Banjarmasin City, South Kalimantan. Using an item response theory approach, a sample size of more than 250 met the requirements for a 1PL analysis. This sample was selected because several aspects of the global warming problem are relevant to the Independent Curriculum's learning outcomes. The sample was selected using a systematic sampling method, with samples drawn from two schools. The researcher used systematic stratified random sampling, in which students were randomly selected based on low, medium, and high levels of conceptual understanding (Istiyono et al., 2023). After determining the students' conceptual understanding levels in the low, medium, and high categories based on the target schools of this study, the researcher conducted a random selection process. Data were collected synchronously in class. The developed test instrument was packaged online using Google Forms.

Data Analysis

This study uses the Rasch model to identify and analyse the characteristics of the tests developed, including validity, reliability, and item difficulty. Rasch analysis has advantages over other analysis methods, namely the ability to analyze test results based on the testee's logit ability and predict missing data (Sumintono & Widhiarso, 2015; Putra et al., 2020). The researcher used the Winstep program version 4.70 to analyze these characteristics. The empirical validity of the test is based on the suitability of each item to the Rasch model. Items fit the model if they meet one of the following criteria: Outfit Mean Square values range from 0.5 to 1.5, Outfit Z-Standard values range from -2.0 to 2.0, and Pt-Measure Correlation values range from 0.4 to 0.85. Test reliability is seen based on Cronbach's Alpha values. Cronbach's Alpha values from the Rasch analysis are interpreted as the level of test reliability (Putra et al., 2020) as shown in Table 1.

Table 1. Test Reliability Level

Cronbach's Alpha Value	Reliability Level
$0.94 \leq r < 1.00$	Excellent
$0.91 \leq r < 0.94$	Very good
$0.80 \leq r < 0.91$	Good
$0.67 \leq r < 0.80$	Fair
$0.00 \leq r < 0.67$	Weak

The level of item difficulty is known based on the logit grouping of the items on the Wright map, based on the standard deviation of the item measure order analysis. Based on these results, the item difficulty level is interpreted as shown in Table 2.

Table 2. Item Difficulty Level

Item Logit Measure Value	Item Difficulty Level
$logit > 0.95$	Very difficult
$0.00 \leq logit < 0.95$	Difficult
$-0.95 \leq r < 0.00$	Easy
$logit < -0.95$	Very easy

Result and Discussion

This research has successfully developed a global warming concept understanding test oriented towards wetlands for high school students through a 4D model, which consists of the define, design, develop, and disseminate stages.

Define Stage

In the define stage, the researcher determined the urgency of developing this test based on the need for a test instrument to measure students' conceptual understanding of global warming, with a focus on wetlands. Interviews revealed that existing tests addressing conceptual understanding of global warming were not directly related to wetlands. This finding aligns with several studies related to the development of global warming conceptual understanding tests. South Kalimantan is a wetland region. Therefore, the developed test provides a solution to this problem. Furthermore, the researcher analyzed high school physics learning outcomes in the Independent Curriculum. The researcher concluded that global warming is a physics topic included in Phase E of the Independent Curriculum. Meanwhile, conceptual understanding is a competency that students must achieve. Furthermore, the topic of global warming was chosen because it has a close relationship with the nature of wetlands and SDG 13.

Design Stage

In the design stage, the researcher designed the test instrument to be developed, including the item matrix, question grid, and item assets. The researcher determined that the test to be developed would be in a multiple-choice format with 20 items. An example of a question outline is presented in Table 3.

Table 3. Example of Item Grid

Learning Objectives	Item Indicator	Item Number	Stimulus
Students can correctly explain the characteristics of peat soil.	Very difficult	I10	Statement
Students can explain the impact of global warming correctly.	Difficult	I20	Phenomenon

Based on the grid in Table 3, the researcher developed the questions shown in Figure 1.

I10. Peat soil has the ability to store carbon because ....
A. low water content
B. the texture of the soil is hard
C. the oxygen content is very high
D. the photosynthesis process is slow
E. the decay is slow due to the anaerobic environment

I20. The Barito River Basin experiences sharp differences in high and low tides, leading to increased flooding and greater drought intensity. This is one of the direct impacts of global warming, as seen from ....
A. climate change
B. feedback effect
C. ozone layer effects
D. changes in the weather
E. global temperature rise

Figure 1. Example of a wetland-oriented global warming concept understanding test question

Figure 1 shows two examples of wetland-oriented global warming conceptual understanding test items as a product of this research. Each item has a diverse stimulus, namely statements, problems, phenomena, and contextual facts. Each question has five answer choices, namely A, B, C, D, and E. Each question answered correctly by the student gets a score of 1. However, if the student's answer is wrong, the score is 0. This is in accordance with the characteristics of dichotomous questions. I10 is an item that tests students' understanding of the characteristics of peat soil. This is very appropriate for the characteristics of the South Kalimantan region, which is predominantly composed of peat soil. Item I10 relates the ability of peat soil to carbon and other elements, where carbon is one of the elements that influence global warming. I20 presents stimuli in the context of phenomena occurring in the Barito River watershed, South Kalimantan. Item I20 tests students' conceptual understanding of the impacts of global warming. This item links the impact of factors causing global warming to the contextual phenomenon of water flow in the Barito River.

Develop Stage

The development stage involves further developing the test instrument design created in the previous stage. Furthermore, empirical testing of the developed test is conducted at this stage. Afterward, a Rasch analysis is conducted to assess the test's quality and characteristics, including validity, reliability, and item difficulty.

The Item Misfit Order analysis determine the validity of the developed test, as shown in Figure 2.

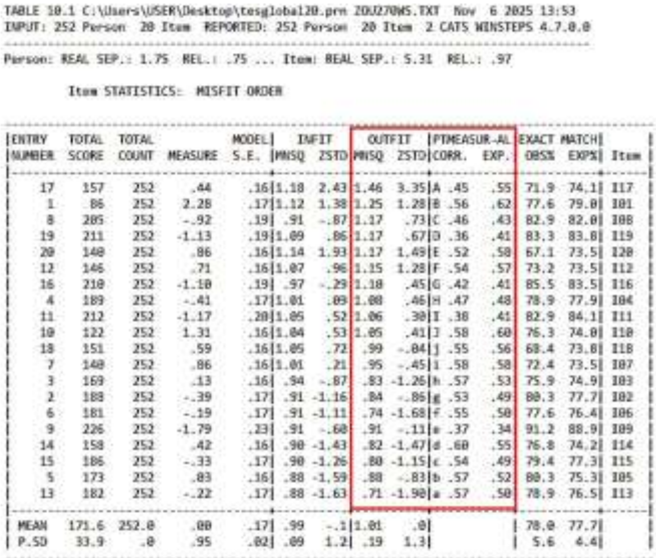
TABLE 10.1 C:\Users\USER\Desktop\tesglobal20.prn ZOU270WS.TXT Nov 6 2025 13:53
INPUT: 252 Person 20 Item REPORTED: 252 Person 20 Item 2 CATS WINSTEPS 4.7.0.0

Person: REAL SEP.: 1.75 REL.: .75 ... Item: REAL SEP.: 5.31 REL.: .97

Item STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
17	157	252	.44	.16	1.18	2.43	1.46	3.35	A .45	.55	71.9	74.1	I17
1	86	252	2.28	.17	1.12	1.38	1.25	1.28	B .56	.62	77.6	79.0	I01
8	205	252	-.92	.19	.91	-.87	1.17	.73	C .46	.43	82.9	82.0	I08
19	211	252	-1.13	.19	1.09	.86	1.17	.67	D .36	.41	83.3	83.8	I19
20	140	252	.86	.16	1.14	1.93	1.17	1.49	E .52	.58	67.1	73.5	I20
12	146	252	.71	.16	1.07	.96	1.15	1.28	F .54	.57	73.2	73.5	I12
16	210	252	-1.10	.19	.97	-.29	1.10	.45	G .42	.41	85.5	83.5	I16
4	189	252	-.41	.17	1.01	.09	1.00	.46	H .47	.48	78.9	77.9	I04
11	212	252	-1.17	.20	1.05	.52	1.06	.30	I .38	.41	82.9	84.1	I11
10	122	252	1.31	.16	1.04	.53	1.05	.41	J .58	.60	76.3	74.0	I10
18	151	252	.59	.16	1.05	.72	.99	-.04	j .55	.56	68.4	73.8	I18
7	140	252	.86	.16	1.01	.21	.95	-.45	i .58	.58	72.4	73.5	I07
3	169	252	.13	.16	.94	-.87	.83	-1.26	h .57	.53	75.9	74.9	I03
2	188	252	-.39	.17	.91	-1.16	.84	-.86	g .53	.49	80.3	77.7	I02
6	181	252	-.19	.17	.91	-1.11	.74	-1.68	f .55	.50	77.6	76.4	I06
9	226	252	-1.79	.23	.91	-.60	.91	-.11	e .37	.34	91.2	88.9	I09
14	158	252	.42	.16	.90	-1.43	.82	-1.47	d .60	.55	76.8	74.2	I14
15	186	252	-.33	.17	.90	-1.26	.80	-1.15	c .54	.49	79.4	77.3	I15
5	173	252	.03	.16	.88	-1.59	.88	-.83	b .57	.52	80.3	75.3	I05
13	182	252	-.22	.17	.88	-1.63	.71	-1.90	a .57	.50	78.9	76.5	I13
MEAN	171.6	252.0	.00	.17	.99	-.1	1.01	.0			78.0	77.7	
P.SD	33.9	.0	.95	.02	.09	1.2	.19	1.3			5.6	4.4	

Figure 2. Item misfit order

Figure 2 shows that all items developed in the wetland-oriented global warming concept understanding test fit the model. This is based on the size of the logit of each item against the accepted criteria limits of Outfit MNSQ, Outfit ZSTD, and PT Measure Correlation logit values (Wright & Linacre, 1994; Subali & Suyata, 2012; Istiyono et al., 2023). Item I17 has an Outfit ZSTD value greater than the criterion, but the Outfit MNSQ and PT Measure Correlation values are still within the criterion limits. Outfit ZSTD depends on the sample size, thus item I17 still fits the model. Items I19, I11, and I09 have PT Measure Correlation values below the criterion. However, these three items have Outfit MNSQ and Outfit ZSTD values within the criterion area, so they fit the model. In the Rasch model analysis, Fit statistics, PT Measure Correlation, Infit MNSQ, and Outfit MNSQ indicate the validity of the developed test. (Bozdağ & Türkoğuz, 2021). The fit analysis provide information that all items that have been developed have characteristics that fit the model. This indicates that all developed items are in accordance with the constructs being measured and function normally in the measurement process (Putra et al., 2020). Therefore, the developed test is categorized as empirically valid.

Items that fit the model can be identified using the Item Characteristic Curve (ICC) and then compared with the model curve. Figure 3 shows the ICC for item I07. The ICC for item I07 in Figure 3 shows that the item fits the model, indicating that the testee's ability is based on the student's response categories (Sumintono & Widhiarso, 2015). The red line depicts the expected model curve. The curves at the top and bottom of the model represent the limits of item characteristics that can be said to fit the model. These curves indicate the Infit MNSQ and Outfit MNSQ values. The response pattern for item I07 falls within this area, indicating that it fits the expected ideal measurement model. The ICCs for all developed test items are shown in Figure 4.

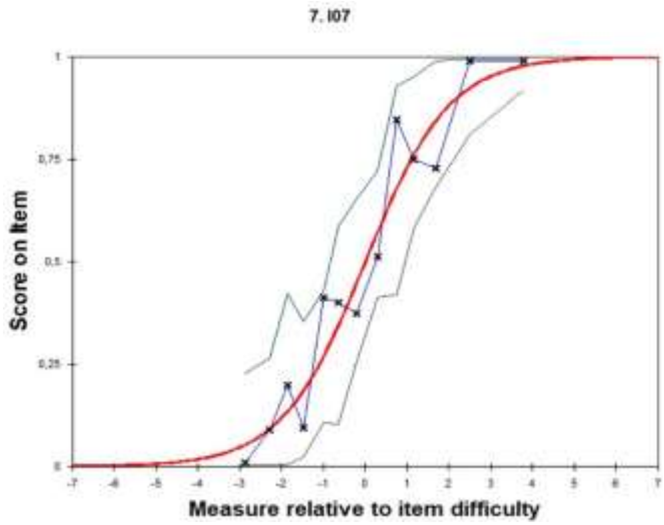

Figure 3. ICC of item 1

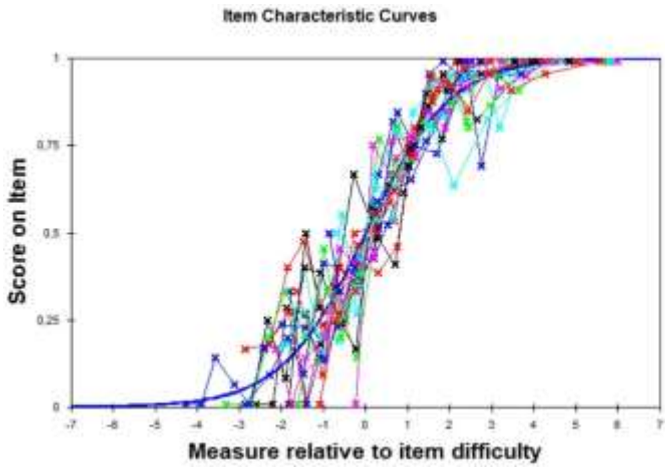

Figure 4. ICC of all items

Figure 4 above shows that the response patterns for all items follow the model. All developed items fit the model. Therefore, the developed test is valid.

The reliability of the test developed is based on the item reliability value and the Cronbach's Alpha value generated based on Rasch analysis. The reliability of the developed test is shown in Figure 5.

Figure 5 shows the person reliability values and item reliability values of the developed test instrument. The item reliability value was 0.97. Cvenic et al. (2022) stated that item reliability is quite high because it approaches the maximum value of 1. Meanwhile, Wright et al. (1994) stated that this value allows us to distinguish a maximum of three levels of ability in a given sample of items. The results of the person reliability values and the item reliability values indicate that the item scale can differentiate students' abilities, while the relationship between the difficulty items is relatively stable (Balta et al., 2022). In line with the person and item reliability, Figure 5 shows the Cronbach's Alpha value of 0.87 from empirical testing in a good category. Referring to Table 1, the developed test has a very good level of item reliability. With this Cronbach's Alpha value, the test developed as a diagnostic tool for students' conceptual understanding is acceptable (Cvenic et al., 2022). The difference in person reliability values and the item reliability values is mainly due to the different number of people and items (Cvenic et al., 2022). Based on the results of the person analysis, the average measured person logit value was 0.92. The person's logit value indicates the average score of all students in completing the given test items. This logit value is greater than 0.00, indicating that students tend to have greater ability than the test difficulty level. However, the Rasch analysis also shows the distribution of items based on their difficulty level. Thus, groups of items with a certain level of difficulty can be obtained. Item separation indicates the testee's ability to answer all levels of item difficulty. This means that testees can be differentiated based on the construct being tested. The item separation index in Figure 5 indicates that the quality of the measurement items in this instrument is very good (Matore, 2021).

```
TABLE 3.1 C:\Users\USER\Desktop\tesglobal20.prn  ZOU270WS.TXT  Nov  6 2025 13:53
INPUT: 252 Person  20 Item  REPORTED: 252 Person  20 Item  2 CATS WINSTEPS 4.7.0.0
--------------------------------------------------------------------------------

     SUMMARY OF 228 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT    MEASURE   S.E.       MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      12.9       20.0        .92     .62        .99    .06   1.01    .10 |
|  SEM        .3         .0        .09     .01        .01    .05    .03    .06 |
| P.SD       4.5         .0       1.41     .17        .21    .83    .51    .92 |
| S.SD       4.5         .0       1.41     .17        .21    .83    .51    .92 |
| MAX.      19.0       20.0       3.35    1.06       1.55   2.79   3.64   3.02 |
| MIN.       3.0       20.0      -2.02     .49        .63  -2.28    .19  -1.93 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .67 TRUE SD    1.24  SEPARATION  1.85 Person RELIABILITY  .77 |
|MODEL RMSE    .64 TRUE SD    1.25  SEPARATION  1.95 Person RELIABILITY  .79 |
| S.E. OF Person MEAN = .09                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .96
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .87 SEM = 1.73
STANDARDIZED (50 ITEM) RELIABILITY = .89

     SUMMARY OF 20 MEASURED Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT    MEASURE   S.E.       MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     171.6      252.0        .00     .17        .99   -.06   1.01    .03 |
|  SEM       7.8         .0        .22     .00        .02    .27    .04    .29 |
| P.SD      33.9         .0        .95     .02        .09   1.17    .19   1.26 |
| S.SD      34.8         .0        .97     .02        .10   1.21    .19   1.29 |
| MAX.     226.0      252.0       2.28     .23       1.18   2.43   1.46   3.35 |
| MIN.      86.0      252.0      -1.79     .16        .88  -1.63    .71  -1.90 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .18 TRUE SD     .93  SEPARATION  5.31 Item   RELIABILITY  .97 |
|MODEL RMSE    .17 TRUE SD     .93  SEPARATION  5.40 Item   RELIABILITY  .97 |
| S.E. OF Item MEAN = .22                                                     |
-------------------------------------------------------------------------------
Item RAW SCORE-TO-MEASURE CORRELATION = -1.00
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000
```

Figure 5. Item reliability

The level of difficulty of the questions can be seen in the item statistic measure order, as shown in Figure 6. This analysis is based on the measured logit values for each item, which have been sorted from the largest logit value to the smallest logit value.

```
TABLE 13.1 C:\Users\USER\Desktop\tesglobal20.prn ZOU869WS.TXT  Nov  8 2025 21: 4
INPUT: 252 Person  20 Item  REPORTED: 252 Person  20 Item  2 CATS WINSTEPS 4.7.0.0
--------------------------------------------------------------------------------
Person: REAL SEP.: 1.75  REL.: .75 ... Item: REAL SEP.: 5.31  REL.: .97

       Item STATISTICS:  MEASURE ORDER

-------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT  |  OUTFIT  |PTMEASUR-AL|EXACT MATCH|      |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| Item |
|------------------------------------+----------+----------+-----------+-----------+------|
|     1     86    252     2.28   .17|1.12  1.38|1.25  1.28|  .56   .62| 77.6  79.0| I01  |
|    10    122    252     1.31   .16|1.04   .53|1.05   .41|  .58   .60| 76.3  74.0| I10  |
|     7    140    252      .86   .16|1.01   .21| .95  -.45|  .58   .58| 72.4  73.5| I07  |
|    20    140    252      .86   .16|1.14  1.93|1.17  1.49|  .52   .58| 67.1  73.5| I20  |
|    12    146    252      .71   .16|1.07   .96|1.15  1.28|  .54   .57| 73.2  73.5| I12  |
|    18    151    252      .59   .16|1.05   .72| .99  -.04|  .55   .56| 68.4  73.8| I18  |
|    17    157    252      .44   .16|1.10  2.43|1.46  3.35|  .45   .55| 71.9  74.1| I17  |
|    14    158    252      .42   .16| .90 -1.43| .82 -1.47|  .60   .55| 76.8  74.2| I14  |
|     3    169    252      .13   .16| .94  -.87| .83 -1.26|  .57   .53| 75.9  74.9| I03  |
|     5    173    252      .03   .16| .88 -1.59| .88  -.83|  .57   .52| 80.3  75.3| I05  |
|     6    181    252     -.19   .17| .91 -1.11| .74 -1.60|  .55   .50| 77.6  76.4| I06  |
|    13    182    252     -.22   .17| .88 -1.63| .71 -1.90|  .57   .50| 78.9  76.5| I13  |
|    15    186    252     -.33   .17| .90 -1.26| .80 -1.15|  .54   .49| 79.4  77.3| I15  |
|     2    188    252     -.39   .17| .91 -1.16| .84  -.86|  .53   .49| 80.3  77.7| I02  |
|     4    189    252     -.41   .17|1.01   .09|1.08   .46|  .47   .48| 78.9  77.9| I04  |
|     8    205    252     -.92   .19| .91  -.87|1.17   .73|  .46   .43| 82.9  82.0| I08  |
|    16    210    252    -1.10   .19| .97  -.29|1.10   .45|  .42   .41| 85.5  83.5| I16  |
|    19    211    252    -1.13   .19|1.09   .86|1.17   .67|  .36   .41| 83.3  83.8| I19  |
|    11    212    252    -1.17   .20|1.05   .52|1.06   .30|  .38   .41| 82.9  84.1| I11  |
|     9    226    252    -1.79   .23| .91  -.60| .91  -.11|  .37   .34| 91.2  88.9| I09  |
|------------------------------------+----------+----------+-----------+-----------+------|
| MEAN  171.6  252.0      .00   .17| .99   -.1|1.01    .0|           | 78.0  77.7|      |
| P.SD   33.9     .0      .95   .02| .09   1.2| .19   1.3|           |  5.6   4.4|      |
-------------------------------------------------------------------------------------
```

Figure 6. Item measure order

Figure 6 shows us that the measured logit value can be positive or negative. The average logit value of the items is 0.00. A positive logit value is greater than the average item logit value. Conversely, a negative logit value is smaller than the average item logit value. A larger positive logit value means the further away the item logit value is from the average. A smaller negative logit value means the further away the item logit value is from the average. Referring to the test average, groups with positive logit scores are more difficult and complex, while groups with negative logit scores are more difficult and complex (Baker et al., 2001; Cvenic et al., 2022; Istiyono et al., 2023). Figure 6 also shows a standard deviation (SD) value of 0.95. Standard deviation functions to group items based on their level of difficulty. Thus, four categories of item difficulty can be grouped based on this value, as explained in Table 2. The average logit value up to +1SD represents the group of items with a difficulty level in the difficult category. This group represents the most difficult group of items developed (Matore, 2021). The average logit value up to -1SD includes the group of items with a difficulty level in the easy category. Furthermore, items with a logit value greater than +1SD from the average logit value are included in the group of items with a difficulty level in the very difficult category. Conversely, items with a logit value less than -1SD from the average logit value are included in the group of items with a difficulty level in the very easy category. This logit value indicates that the item can differentiate student abilities (Bozdağ & Türkoğuz, 2021).

Grouping the level of item difficulty can refer to the item wright map as presented in Figure 7. This grouping is based on the measured logit value for each item, the mean logit value, and its standard deviation. Thus, the position of each item can be clearly seen through the Wright map of this item. The Wright map also demonstrates good test targeting for the sample (Cvenic et al., 2022).

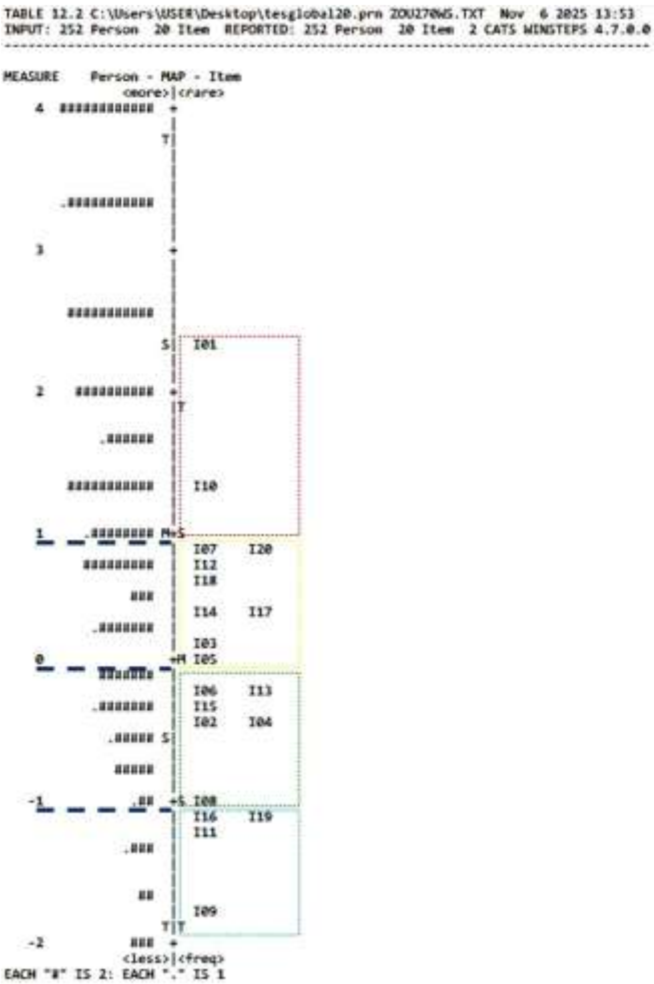

Figure 7. Item wright map

Figure 7 shows that the average logit value of the measured items is 0. The items are sorted from top to bottom, meaning from most difficult to easiest. M represents the average item difficulty and testee ability, S represents the distance of one standard deviation from the mean, and T represents the distance of two standard deviations from the mean (Bozdağ & Türkoğuz, 2021). The average of person ability is slightly higher than the average item difficulty, indicating that the items developed were generally easy for the testee to perform (Matore, 2021). There are four separate item groups based on their difficulty level. There are two items with a difficulty level in the very difficult category, namely I01 and I10. However, I01 has the highest level of difficulty among the other items. There are eight items in the difficult category. I07, I20, I12, I18, I14, I27, I03, and I05 are items that are included in the difficult category. Meanwhile, six items—I06, I13, I15, I02, I04, and I08—are categorized as easy. Very easy items are I16, I19, I11, and I09. I09 is the easiest item among all the items developed. Some items are categorized as easy, but this is not critical because all students have questions within the logit range of ±1 around their ability, as required for good measurement (Wright & Linacre, 1994; Cvenic et al., 2022).

Referring to the analysis results shown in Figure 7, it is known that the developed test has varying levels of item difficulty. This item difficulty index describes the overall level of test difficulty (Azwar, 2015; Istiyono et al., 2023). This level of test difficulty can also be seen in the test information function curve presented in Figure 8.

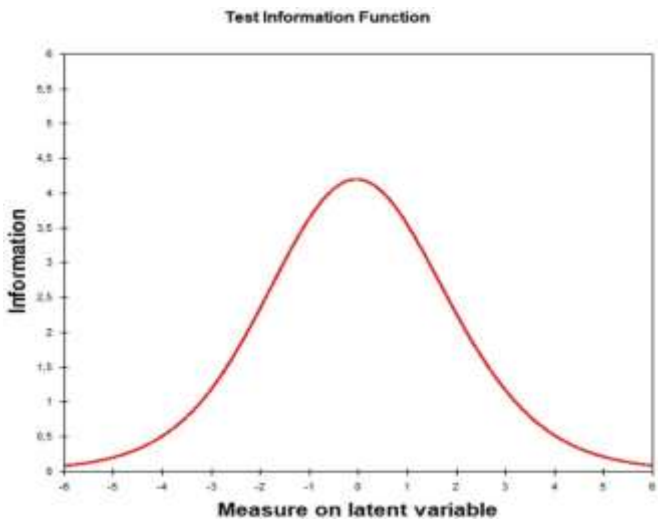

Figure 8. Test information function

Figure 8 shows a normally distributed test information function curve. The horizontal axis indicates the ability level. Meanwhile, the vertical axis represents the magnitude of the test information function. The peak of the curve on the vertical axis indicates a relatively high information function value. The peak of the curve on the horizontal axis is at the logit value of 0, indicating that the test difficulty level is generally in the moderate category. This means that the developed test items are optimal in generating information when administered to students with moderate abilities. Testee scores describe the testee's ability; high testee scores indicate high ability, and vice versa (Istiyono et al., 2023). Based on this curve, it is also known that the developed test has items with an evenly distributed level of difficulty. In other words, they are neither too difficult nor too easy. The discriminatory power of each item meets the specified criteria, indicating that all items are acceptable and do not need to be eliminated (Boone et al., 2014; Bond, 2015). This is a positive result because increasing cognitive complexity can organize conceptual constructs, making the resulting test applicable in different educational systems (Cvenic et al., 2022). Therefore, the developed test is suitable for classroom use.

Dissemination Stage

A wetland-oriented global warming conceptual understanding test was completed during the dissemination phase, conducted by physics teachers in Banjarmasin during the socialization of the learning module. Furthermore, this test can be widely used in physics teaching.

Conclusion

This research has produced a valid and reliable global warming concept understanding test instrument oriented towards wetlands based on Rasch analysis. All test items showed a good fit with the model and had a proportional distribution of difficulty levels: very difficult, difficult, easy, and very easy. The validity of the test developed based on Rasch analysis is in the good category. The test reliability according to Cronbach's Alpha is in the good category. The test produces optimal information when administered to students with moderate abilities. The interaction relationship between the testee and the items is generally in the very good category. Although the developed test has been tested on a sample that meets the 1PL rules, it needs to be further tested on a larger sample to achieve more optimal test characteristics. The findings revealed in this study provide an opportunity for further researchers to determine the effectiveness of students' conceptual understanding and design more appropriate learning solutions. Furthermore, this instrument accurately and contextually measures students' understanding of global warming. It has the potential to support strengthening climate literacy and the implementation of sustainable education in line with the goals of SDG 13.

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Conflicts of Interest
The authors declare no conflict of interest in this study.

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