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Identification of Students' Comprehension of Radiation Concept Using Rasch Analysis

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Abstract

This community service was conducted using a survey method. The survey aimed to test the understanding of high school students regarding the dangers of radiation exposure from the surrounding environment. Participants in this activity were 48 students (35 science students and 13 social science students) from a high school in Majalaya, Bandung Regency. The instrument used was a two-tier diagnostic test consisting of 4 essay questions related to physics concepts concerning radiation exposure. The analysis of the test results was divided into two parts: conception analysis and Rasch analysis. The conception analysis was done by interpreting students' answers and categorizing them into five conception categories: Full Understanding (FU), Partial Understanding (PU), Misconception (MC), Not Understanding (NU), and No Coding (NC). This categorization was presented in percentage form. The Rasch analysis was conducted based on the distribution of students' answers and item bias detection to identify the spread of students' answers to each question item and the biases present. First, the conception analysis results showed that 53% of students were included in the FU category, while only 5% were in the Not Understanding (NU) category. This indicates that students' understanding of the dangers of radiation exposure is quite good, as more than half of the participants are in the FU category. Second, the Rasch analysis results based on the distribution of students' answers showed that more students could answer basic comprehension questions compared to classification and analysis-based questions. Additionally, the Rasch analysis results based on item bias detection indicated that there was no gender or academic major bias in the four question items.

Keywords: Conception analysis, misconception, radiation, Rasch analysis

1. Introduction

Radiation is the process of energy propagation without passing through an intermediary medium. Based on its ability to ionize matter, radiation is divided into two types: ionizing radiation and non-ionizing radiation. In the electromagnetic wave spectrum, non-ionizing radiation includes waves with low energy, such as radio waves, ultraviolet rays, infrared, and visible light. On the other hand, sources of ionizing radiation include waves with high energy, such as X-rays and gamma rays (Sudarti et al., 2023).

The frequency of electromagnetic waves emitted with radiation energy adheres to the photon energy equation proposed by Max Planck. According to this equation, the shorter the wavelength, the higher the energy of the emitted electromagnetic radiation source. Conversely, the longer the wavelength, the lower the energy produced by the radiation source. The level of exposure to electromagnetic waves of various frequencies changes significantly, which can affect human health.

In daily life, humans are exposed to various types of radiation, including sunlight which produces ultraviolet waves. Besides that, there is also wave radiation from mobile phones. Sunlight emits ultraviolet (UV) waves with different types, namely Ultraviolet A (UV-A) and Ultraviolet B (UV-B) (Salvadori et al., 2020). UV-A is the largest component of ultraviolet rays reaching the earth, accounting for about 95%. The intensity of this type of UV ray is much higher compared to UV-B.

Besides ultraviolet, another common type of radiation in the environment is radiation from mobile phones, which involves radio waves. Radio waves operate within the frequency range of 450-1800 MHz and have wavelengths of 0.1-10 meters. The radio waves used in mobile phones are useful for quickly transmitting data wirelessly, and for voice and video communication. According to data from National Socio-Economic Survey – Indonesian Central Statistics Agency, the proportion of individuals who own a cellphone in the 15-24 year age range reaches 92% in 2023 (Susenas Kor BPS, May 2024).

Besides offering many benefits, ultraviolet radiation and mobile phones can also cause side effects in humans. Between 2020 and 2024, there were 171 Scopus articles discussing the dangers of electromagnetic wave radiation, as shown in Figure 1. The World Health Organization (WHO) has researched and found no increased risk of cancer among mobile phone users. However, there are still side effects associated with long-term mobile phone use. In recent years, more research has focused on the impact of prolonged mobile phone use on the human body's biological condition, including metabolic disorders and neurotransmitter disruption, which can affect cognitive and emotional behavior (Hu et al., 2021).

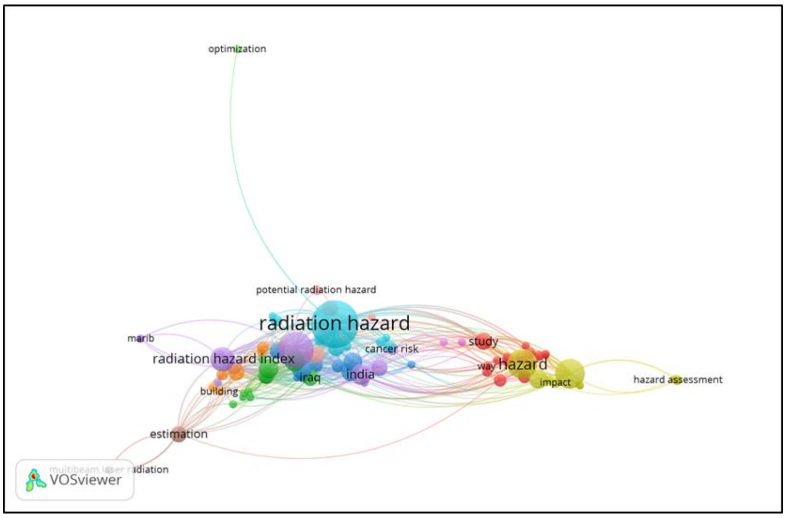

Figure 1: Mapping of 171 Scopus articles (2020-2024) related to Radiation Hazards using VOS viewer

The struggles to protect oneself and the environment from the dangers of radiation are called radiation protection. Radiation protection is regulated in documents included in the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). For radiation protection from sunlight, the term UV Index is introduced (Salvadori et al., 2020). The higher the UV Index, the greater the intensity of ultraviolet radiation received by the skin. UV radiation increases the risk of short-term damage such as heatstroke and long-term damage such as premature aging and DNA structure changes. Those damages can potentially lead to skin cancer (Gromkowska-Kepka et al., 2021).

In the case of mobile phone use, based on ICNIRP guidelines, it is recommended that the Specific Absorption Rate (SAR) value be less than 1.6 W/kg for all types of phones (Seetharaman et al., 2022). The SAR value indicates the strength of mobile phone radiation absorbed by the human body. Each phone has a different SAR value. SAR refers to the maximum energy limit of electromagnetic waves (watts) from mobile phone radiation absorbed by 1 kilogram of body tissue when the phone is in use. Additionally, ICNIRP recommends screen time, or the time spent staring at gadget screens, be less than 2 hours per day (Hardell et al., 2021).

The purpose of this survey is to identify students' level of comprehension regarding the dangers of radiation around them and efforts to protect themselves from such dangers. Each student has different knowledge, causing discrepancies between the students' understanding of radiation phenomena and the actual concepts (Darmana et al., 2021). Rasch analysis is used to help analyzing the collected data. The Rasch model is an advanced assessment theory that can categorize the calculation of items and persons on a distribution map (Aminudin et al., 2019; Darmana et al., 2021; Samsudin et al., 2024). Through this analysis, students' level of understanding of the dangers of radiation exposure can be identified.

2. Methodology

This community service was carried out using a survey method at a high school in Majalaya District, Bandung Regency. The survey aimed to assess students' understanding of radiation exposure hazards in their environment. The survey method was deemed appropriate for analyzing students' perceptions and concepts related to this material as a real-life phenomenon encountered daily (Siedlecki, S. L., 2020). The participants in this survey were 48 students, consisting of 35 science students and 13 social science students. They are comprising 20 male students and 28 female students. The instrument used in this community service activity was a two-tier diagnostic test, consisting of 4 essay questions related to physics concepts concerning radiation exposure. The two-tier diagnostic test instrument can be used to determine students' understanding of concepts (Tukiyo et al., 2023). Students were given 15 minutes to complete the test.

The test results analysis was divided into two parts. First, the analysis of students' conceptions involved interpreting their combined answers. Interpretation of these answers was categorized into five conception categories: Full Understanding (FU), Partial Understanding (PU), Misconception (MC), Not Understanding (NU), and No Coding (NC) (Samsudin et al., 2017). FU represents students who have a complete and confident understanding of a concept. PU indicates students who only partially understand a concept. They cannot explain the phenomenon comprehensively and answer with uncertainty. MC refers to students whose conception is not aligned with scientific phenomena. But they believe in their answers. NU criteria apply to students who do not understand the concept at all. NC indicates students who cannot answer the questions or whose answers are incomplete. Scoring guidelines and conception categorization used are showed in Table 1.

Table 1: Scoring guidelines and conception categorization

Conception Category	Code	Tier 1		Tier 2		Total Score
		True	False	Sure	Not Sure	
Full Understanding	FU	2		1		3
Partial Understanding	PU	2			0	2
Misconception	MC		0	1		1
Not Understanding	NU		0		0	0
No Coding	NC	Incomplete Answer				(Empty)

The second test result analysis is Rasch analysis using ministep 5.7.4.0 software. The outcomes ontained are distribution of student responses and detection of item bias. Analysis based on response distributions was conducted to identify which test items were relatively easy (answered correctly by all students) and difficult (where some students struggled to answer). Meanwhile, analysis based on item bias detection aimed to determine whether any of the four question items favored or disadvantaged a particular gender or academic major. The item bias detection results showed no bias if the probability values were not less than 5% or 0.05 (Darmana et al., 2021).

3. Results and Discussion

3.1. Conception Analysis

After data processing, the categorization results of students' conceptions for each question item are presented in Table 2.

Table 2: The categorization results of students' conceptions for each question item

Conception Category	Q1		Q2		Q3		Q4	
	f	%	f	%	f	%	f	%
FU	33	69%	26	54%	23	48%	20	42%
PU	7	15%	6	13%	11	23%	1	2%
MC	5	10%	6	13%	5	10%	11	23%
NU	0	0%	2	4%	3	6%	4	8%
NC	3	6%	8	17%	6	13%	12	25%
Total	48	100%	48	100%	48	100%	48	100%

In Table 2, it can be observed that question number 1 (Q1) mostly can be answered by students. 69% of the students were included in Full Understanding (FU) category. For question number 2 (Q2), 54% of students have full comprehension of the given question. More than 50% of students were able to answer Q1 and Q2 because these questions pertained to Factual Knowledge, referring to terms, facts, and detailed information understood by the students (Muhiddin et al., 2024). Specifically, Q1 discussed the relationship between wavelength and energy received from electromagnetic radiation. While Q2 focused on the effects of mobile phone usage. It indicates that these questions contained factual information already acquired by the students.

On the other hand, question number 3 (Q3) and number 4 (Q4) were included under Conceptual Knowledge. It refers to classification, principles, and specific theories about electromagnetic wave radiation. It is evident that less than 50% of students were able to answer these questions correctly. Additionally, the Misconception (MC) rate for Q4 was high at 23%. This suggests that students tended to have misconceptions when it came to questions requiring classification based on scientific facts (Gusmalini & Wulandari, 2020). Misconceptions can arise due to various factors such as differing perspectives, student conditions, humanistic thinking, faulty reasoning, incorrect intuition, and the influence of information from books or social media. To address misconceptions, students must grasp concepts scientifically, provide evidence validating their misconceptions, and establish logical connections between evidence and understanding (Muhiddin et al., 2024).

Based on Figure 2, the level of student comprehension viewed through the average percentage of all four questions. It shows that 53% of students had a Full Understanding. Only 5% of students were in Not Understanding (NU) category. This indicates that more than half of the participants have grasped the concepts of radiation exposure and its dangers. Additionally, 14% of students experienced Misconceptions (MC), often due to incomplete understanding of concepts (Suprapto, 2020). Furthermore, another cause of misconceptions is the confusion between different concepts (Rosa & Widiawati, 2022).

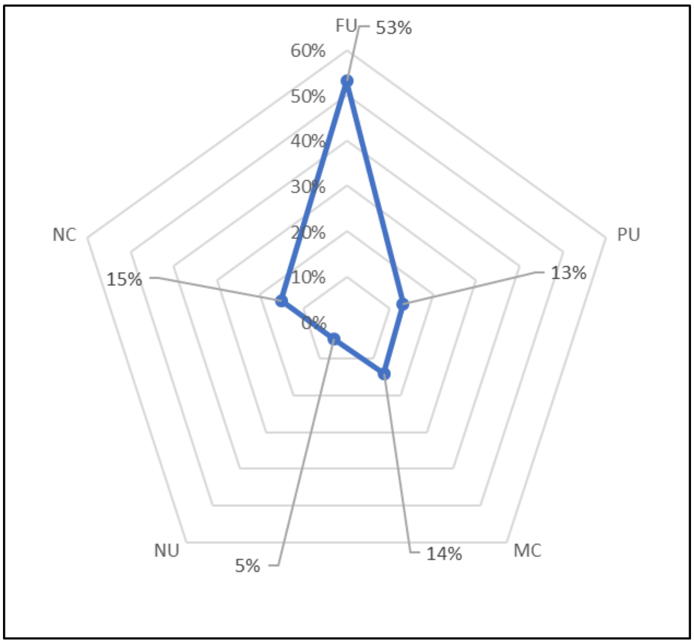

Figure 2: The average percentage of students' level of comprehension in the FU, PU, MC, NU, and NC category

3.2. Rasch Analysis

The first Rasch analysis was conducted based on the distribution of student responses. The results are presented in the form of a Wright map, as shown in Figure 3. It can be observed that 38 students were able to answer all the given questions out of a total of 48, indicated by green boxes. Five students were unable to answer Q3 and Q4, shown in red boxes. Referring to Table 2, it is evident that Q1 and Q2 were easier for students to answer compared to Q3 and Q4. This difference can be attributed to the types of questions; Q1 and Q2 focused on basic understanding, while Q3 and Q4 involved classification and analysis tasks (Muhiddin et al., 2024).

The second Rasch analysis was conducted to detect any biases that may exist. Item bias detection was performed by analyzing the Differential Item Functioning (DIF) from the data processing using the Rasch Model. Figure 4 shows that the probability values for all four test items were not less than 5% or 0.05. This indicates that there is no bias based on gender or academic major, meaning no specific gender or academic track found certain questions easier than others. However, Figure 4 revealed a notable difference in the responses of female social science students. It is marked by the blue line. The curve for female social science students significantly differed from the trends of the other three curves. It is likely due to less serious engagement in answering the questions (Siedlecki, S. L., 2020).

Based on the conception analysis results, there are still 5% of students categorized as NU (Not Understanding) and 14% categorized as MC (Misconception). When related to the test items analyzed, the Rasch analysis indicates that none of the four question items exhibited bias. This means that the question items did not favor any specific gender or academic major. Therefore, the efforts to enhance students' comprehension of concepts should focus on strengthening their conceptual grasp. This can be achieved through comprehensive and detailed socialization regarding the dangers of radiation and its prevention measures (Ali et al., 2021; Shafiq & Mehmood, 2024).

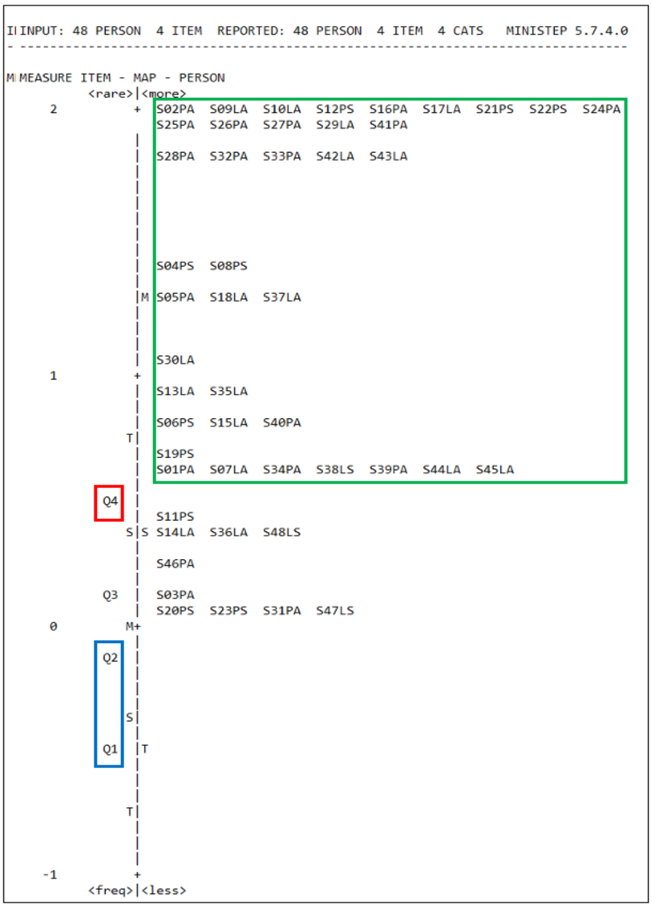

Figure 3: Results of Variable Analysis (Wright) map

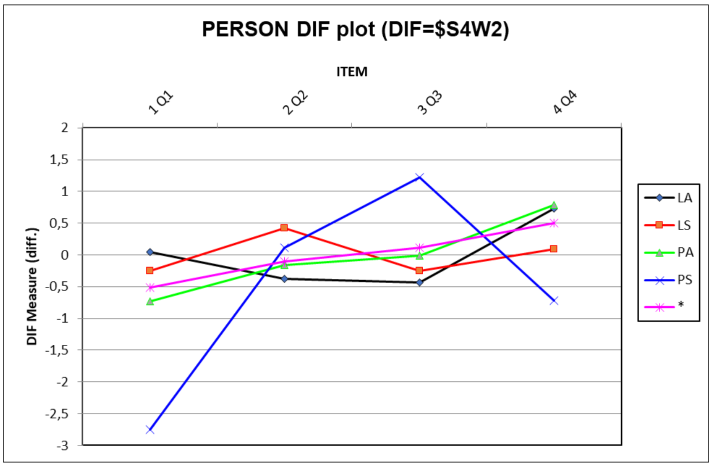

TABLE 30.4 Analisis Soal (Konsepsi) Rasch.xlsx ZOU062WS.TXT
INPUT: 48 PERSON 4 ITEM REPORTED: 48 PERSON 4 ITEM 4 CATS MINISTEP 5.7.4.0

DIF class/group specification is: DIF=$S4W2

PERSON CLASSES	SUMMARY DIF CHI-SQUARED	D.F.	PROB.	BETWEEN-CLASS/GROUP UNWTD MNSQ	ZSTD	ITEM Number	Name
4	4.3229	3	.2276	2.4884	1.58	1	Q1
4	1.1532	3	.7639	.5208	-.45	2	Q2
4	6.1736	3	.1028	3.3295	2.08	3	Q3
4	2.9183	3	.4032	2.0003	1.23	4	Q4

Figure 4: DIF analysis results

4. Conclusion

Based on the conception analysis results, it can be concluded that the level of comprehension among high school students in Majalaya regarding the dangers of radiation and its prevention measures is quite satisfactory, as indicated by the 53% of students categorized as FU (Full Understanding). However, there are still 5% of students categorized as NU (Not Understanding) and 14% as MC (Misconception). Based on the Rasch analysis results, the four test items showed no bias based on gender or academic major. This means that the test items were sufficiently general and did not favor any specific gender. So that, to achieve a better understanding of the concepts, researchers can focus on reinforcing conceptual understanding. The approach is to provide detailed and comprehensive education regarding the dangers of radiation and its prevention measures. This effort is aimed at increasing awareness among high school students about the dangers of radiation in their environment.

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