



## The development of a three tier diagnostic test to identify misconception on food chain feeding relationships



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### ABSTRACT

This study was aimed to develop a Three-Tier Diagnostic Test instrument to identify students' alternative conceptions about Food Chain Feeding Relationships. This instrument was developed based on stages of development proposed by Treagust. This study involved 102 students of grade VII. There were 4 students included in the interview, 28 students answered the open-ended questions, and 70 students were involved in the implementation of instrument developed. The instrument items' content was then validated by five expert judgment. The analysis showed that the Content Validity Ratio and Content Validity Index value for nine items was 1, while an item acquired 0.6 value. This indicated that Food Chain Feeding Relationships Diagnostic Instrument (FCFRDI) is valid and feasible to be tested on students. The test result data were analyzed using the Rasch Model to determine the item fit and reliability. The difference between item reliability value and the person reliability demonstrated a significant result, which means that the instrument developed has good item quality. Overall, it can be concluded that the FCFRDI developed has met the content and empirical validity so that it can be used to identify students' misconceptions.



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### Introduction

Ecological imbalance can occur due to various factors such as natural disasters, poaching, deforestation, and large-scale nature exploitation. In consequence, the ecological existence which supports the life of organisms on earth is threatened. The effects could be seen on every kind of life, one of which was the food chain. If a species in the food chain is threatened or extinct, it can affect other species. For example, if predators are reduced in

number or become extinct, then the prey can be excessive. The domino effect that resulted from the excessive number of preys can change the trophic level below it. If the preys are herbivores, it can cause an increasing number of herbivores, negatively impacting producers' regeneration. The presence of producers in an ecosystem provides genetic variability to a population, reduces climate change, and provides habitat for certain species (Muller, 2000).

Interference in the food chain can affect all organisms in the ecosystem. This fact shows that the organisms involved in the food chain are interdependent and connected. The food chain is a fundamental concept in ecological studies. It is studied by grade VII students in the interaction of living things with their environment material. This concept is essential for students to learn to increase environmental awareness as a generation involved in environmental conservation (Hovardas, 2013). Therefore, they need to acquire a good understanding of ecology, particularly the food chain. So that in the future, they can participate and responsible in striving for a balanced ecosystem. Students as a generation who will be involved in preserving the environment and the earth should be given a good understanding of ecology, especially the food chain. This can be acquired from school.

Students often build alternative conceptions or misconceptions during the teaching and learning process because they are influenced by their pre-existing conceptions and beliefs (Hammer, 1996; Peşman & Eryilmaz, 2010; Vosniadou, 2012). Students' alternative conceptions before learning science are formed due to their experiences and interactions with their physical and social environment (Özmen, 2004). If the students' preconceptions are not correct, it will be challenging to fix them to become scientific conception. If they are not resolved, it will allow for continuous misconceptions. Therefore, the identification of alternative conceptions is crucial in learning science.

Various methods have been used to explore students' conceptual understanding, such as interviews, concept maps, open-ended questions, multiple choices (Loh et al., 2014; Tan et al., 2002), multiple multilevel choices (Korur, 2015), two-tier multiple choices (Chandrasegaran et al., 2007; Nahadi et al., 2014; Utami et al., 2019), three-tier multiple choices (Cetin-Dindar & Geban, 2011; Gurcay & Gulbas, 2015; Taslidere, 2016), four-tier multiple choices (I. S. Caleon & Subramaniam, 2010; Kaltakci-Gurel et al., 2017) and five-tier multiple choices. All of these methods have benefits and drawbacks in expressing students' conceptions. A tiered multiple choices test (tier test) is preferred to

diagnose students' misconceptions (I. Caleon & Subramaniam, 2010).

Based on the information above, the three-tier test diagnostic instrument needs to be developed. This instrument consists of three levels: level one expressing students' cognitive level, level two showing the reasons for choosing answers at the first level, and level three describing students' confidence level in choosing their answer. The three-tier test is considered sufficient to reveal students' alternative conceptions (Arslan et al., 2012).

This test instrument is considered more valid and reliable for evaluating alternative conceptions (Peşman & Eryilmaz, 2010). Therefore, this study was aimed to develop The Food Chain Feeding Relationship Diagnostic Instrument. The results of this study will enrich the literature because there are still limited studies that choose this topic and focuses on food chain material.

## Method

The Food Chain Material Diagnostic Instrument (FCFRDI) was developed by modifying the Treagust instrument development procedure (Treagust, 1988). The stages of developing the instrument were divided into three stages: defining the concept, analyzing students' alternative conceptions, and developing diagnostic instruments (Figure 1). Generally, it is illustrated as follows:

### Defining the Concepts

A literature review was carried out to formulate the limitation of problems regarding the food chain material. Various sources such as books, scientific articles, and the internet were used to build a conceptual framework. The concept found was used to construct concept maps and propositional statements. Furthermore, propositional knowledge was examined by three validators. The validation results showed that the propositional statements were following the Science concept so that it can be verified that grade 7 students studied the concept.

### Analyzing students' alternative conceptions

Students' alternative conceptions were obtained by conducting an interview and delivering an open-ended questionnaire to 28 students. This was intended to explore students' ideas and assess students' understanding of the food chain. The

questions written on the open-ended questionnaire were served as a guide for interviewing other students separately. This aims to explore students' understanding and complement the weaknesses of conducting interviews and open-ended questions. The questions had not included the propositional statements prepared in the previous stage. Based on students' answers, FCFRDI stage 1 was developed by considering the literature review, concept maps, and propositional statements. Different alternative conceptions were used as distractors for level 1 and level 2 final version items.

**Developing a diagnostic instrument**

The FCFRDI instrument consists of 10 three-tier questions. The first level measured students' cognition, the second level revealed the reasons, and the third level described students' confidence in choosing answers. The developed

instrument was then validated based on content validity and empirical validity procedure. The content validity test used expert judgment (2 assessment experts and three education experts). Furthermore, the validated instruments were processed using the Content Validity Ratio (CVR) and Content Validity Index (CVI) methods. The CVR value calculation was based on the Lawshe equation (Lawshe, 1975).

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}}$$

Description:

n: Validator who declared the instrument valid

N: The total number of validators

The CVI category's calculated CVR was then included in deciding whether the items were valid or not. The range of criteria from CVI calculation is presented in Table 1.

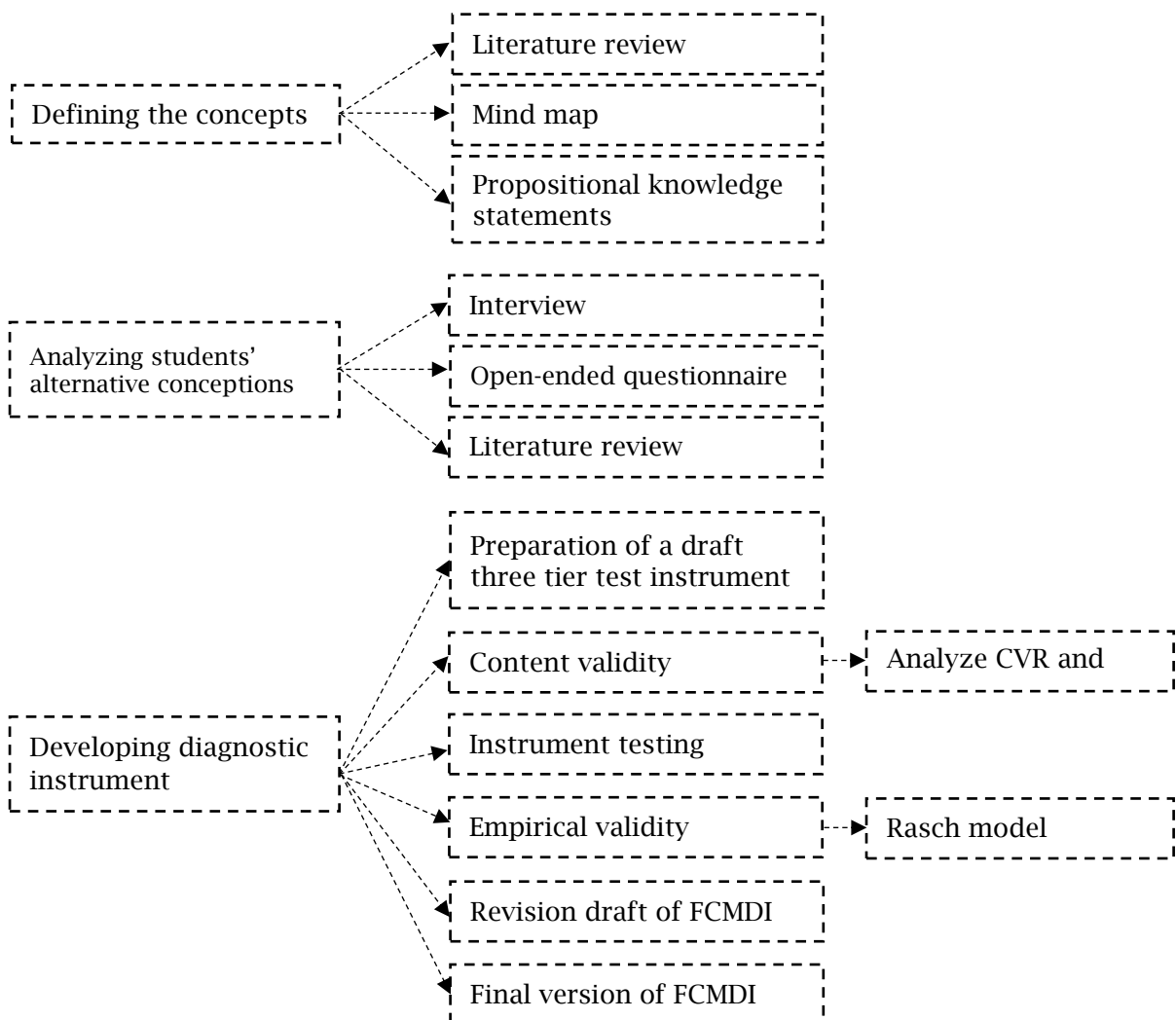


Figure 1. FCFRDI development stages

Table 1. CVI calculation category

Range	Category
$CVI \geq 0.68$	Very relevant
$0.34 \leq CVI \leq 0.67$	Relevant
$CVI < 0.34$	Not relevant

(Wilson et al., 2012)

After the instrument was validated, the instrument was tested on several grade VIII students who had studied the food chain material. The trial was carried out to get student responses and used as a reference for analyzing the empirical validity test. The empirical validity test used the Minister Rasch Model. Rasch can predict missing data based on systematic responses (Sumintono & Widhiarso, 2015). The empirical validity test conducted was a test item appropriate level; the reliability test compared person reliability and item reliability value. The item fit test criteria referred to the value of outfit means square (MNSQ), outfit Z-standard (ZSTD), and point measure correlation (Boone et al., 2014).

#### Participants

This study involved 102 students of grade VIII semester one 2020/2021 from 3 junior high schools, namely SMPN 1 Suliki, SMPN 1 Guguak, and SMPN 2 Mungka, Lima Puluh Kota Regency, West Sumatra. The research subjects were divided into three groups for an interview, an open-ended questionnaire, and instrument testing. All participants involved in the study had

studied food chain material in the interaction of living things with the environment chapter. Interviews were conducted, and an open-ended questionnaire was given simultaneously at SMPN 1 Suliki. There were four students involved in the interview, a girl and three boys. During the interviews with four students, 28 students (32% male and 68% female) filled out the open-ended questionnaire. Furthermore, instrument trials were carried out in three schools with a total sample of 70 students.

## Results and Discussion

### Defining concepts

This study was initiated with a literature review to determine the limitation of the food chain's problems. The first step was done by analyzing the core competence and basic competence of curriculum 2013 for junior high school level. The core competence analysis and basic competence were carried out to determine the materials' scope. Furthermore, core competence and basic competence were translated into competency achievement indicators. The indicators contain the guidelines for making the test blueprints. Subsequently, the construction of concept maps and propositional knowledge statements was carried out.

#### Tier I: Cognitive

1. Eating and being eaten activities in the food chain were described schematically in a straight line from the first trophic level to another level. Which of the following statement is correct about the chain?
  - A. The longer the food chain, the least amount of energy acquired by the producers
  - B. The longer the food chain, the greater the energy transferred from producers to consumers
  - C. The longer the food chain, the top consumers get the most energy
  - D. The longer the food chain, the less energy the top consumer will get**

#### Tier II: Reasons

- A. **The top consumers get the least amount of energy because it has previously been absorbed by the lower trophic and some other energy is released**
- B. The amount of energy obtained by the producer depends on the amount of energy that must be divided into the trophic levels
- C. The energy produced by the first trophic level depends on the number of organisms at the other trophic level
- D. The top consumers get a lot of energy due to energy accumulation from the lower trophic levels

#### Tier III: Confidence

- A. Yes
- B. No

Figure 2. FCFRDI example (translate version)

### Misconception analysis

Misconception analysis was aimed at exploring the information about students' alternative concepts through interviews and free test. The result of the interview signifies that students' understanding was not following scientific conception. For example, they thought that the food chain was an arrangement of food, and producers occupy the ecosystem's energy. They also thought that the energy flow was similar to humans eating rice, in which food to defecation process. Some of them also admitted that they did not understand this material. Students' answers in the test also strengthened the description of the interview result. Almost all students left their answers blank in the test. This proved that students might have a lack of knowledge conception. Lack of knowledge is a condition where students do not have adequate recognition of learning material. This revealed that the interview analysis and test were insufficient to build a tiered test at level II. Therefore, literature identification was needed. Various sources, such as journals, books, and the internet, are used as references. Besides, students' questions and answers during midterm exams were also taken into consideration. The sources obtained were then analyzed and synthesized to complete the instrument (Figure 2).

### Validation test

#### Content validity

The FCFRDI instrument that had been constructed was then validated based on content validity and empirical validity aspects. The content validity was analyzed using CVR and CVI. The ten items tested on students were considered valid and relevant to the CVR and CVI value categories. The value of CVR and CVI for the nine items was one, and item number eight had the value of 0.6. The items acquiring one were confirmed to meet the relevant category criteria while the item with 0.6 values in the relevant category. This showed that FCFRDI was considered valid and can be tested on respondents to obtain empirical validity. FCFRDI, which had been validated and revised, was tested on 70 students consisting of 26 students from SMPN 1 Mungka District (70% female and 30% male), 23 students from SMPN 1 Guguak (53% female and 47% male), and 19 students from SMPN 1 Suliki (74% female and 26% male).

### Empirical Validation

The data from the test items were analyzed using the Minister Rasch Model to obtain empirical validity. The empirical validity was the item appropriate level test and reliability test by comparing the value of person reliability and item reliability. The item fit level was based on outfit MNSQ (Mean Square), Outfit ZSTD (Z-Standard), and Pt Measure Corr criteria. The Rasch model's item analysis result resulted in nine items that met the outfit MNSQ (Table 2) and Outfitted ZSTD (Z-Standard) criteria (Table 3). An item did not meet outfit MNSQ, but it could fulfill the outfit ZSTD (Z-Standard) criteria.

Table 2. Outfit mean square (MNSQ)

Item number	Outfit mean square (MNSQ) value	
	0.5 < MNSQ < 1.5	Criteria
1	2.48	Rejected
2	1.17	Accepted
3	1.15	Accepted
4	1.13	Accepted
5	1.00	Accepted
6	0.80	Accepted
7	1.04	Accepted
8	1.00	Accepted
9	0.87	Accepted
10	0.62	Accepted

The items that did not meet Outfit MNSQ criteria are reconsidered their eligibility by referring to the outfit ZSTD criteria. Since the outfit ZSTD value met the criteria, the item could be accepted (valid). The items that do not meet one criterion can still be included to be valid so that the questions do not have to be changed or replaced (Boone et al., 2014).

Table 3. Outfit ZSTD value

Item number	Outfit Z-Standard (ZSTD) value	
	-2.0 < ZSTD < +2.0	Criteria
1	1.26	Accepted
2	0.57	Accepted
3	0.86	Accepted
4	0.65	Accepted
5	0.14	Accepted
6	0.04	Accepted
7	0.24	Accepted
8	0.14	Accepted
9	-0.75	Accepted
10	-1.62	Accepted

The items' reliability was determined by comparing the person reliability value with the item reliability value (Table 4). The significant difference between person reliability and item reliability shows that



students' answers consistency is weak, while the quality of the items is good (Sumintono & Widhiarso, 2015).

Table 4. Item reliability and person reliability category

Reliability	Value	Category
Person	0.47	Low
Item	0.81	Good

**The percentage of the correct answers in the developed tier test**

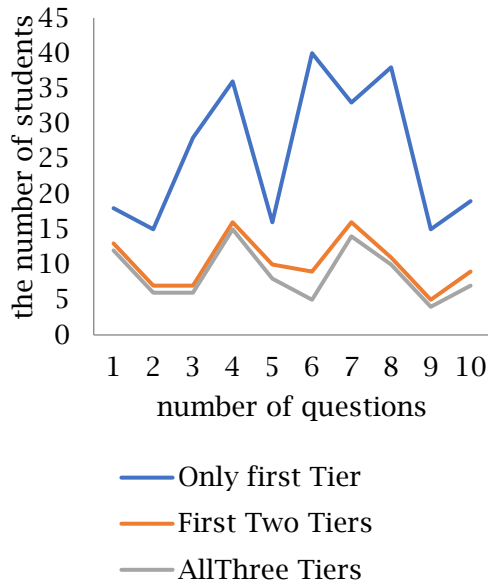


Figure 3. The percentage of the correct answers

The Figure 3 revealed the students' correct answers for the first tier, first and second tier, and all tiers of FCFRDI items. The percentage of students who answered correctly for the first tier was 36.11%, the first two tiers were 15.37%, and All tiers was 12.98%. The average percentage of students who answered correctly for the first and the second tier was 20.74%. The difference in the percentage came from false positives and lack of knowledge. False Positive occurred when students chose the correct answer at the first tier but wrong at the second tier, and they were sure about their answer in the third tier.

In contrast, lack of knowledge occurred when the students correctly answered in the first tier, but they gave the wrong answer in the second tier and were unsure about their answer in the third tier (Kaltakci Gurel et al., 2015). These results implied that students had a shallow understanding of the food chain material

and had the potential to have different conception level for each item. Therefore, further research is needed to identify and map the possible alternative conceptions and misconceptions related to the food chain material.

Furthermore, teachers can use this instrument to identify students' understanding before and after studying the food chain material. It also helps teachers develop appropriate teaching and learning processes to achieve the learning objectives to overcome misconceptions experienced by students. Moreover, teachers can also use diagnostic test instruments to evaluate their learning and take samples quickly (Arslan et al., 2012; Liampa et al., 2019).

**Conclusion**

According to the findings of this study, it can be concluded that the developed FCFRDI was a reliable and capable instrument for assessing students' understanding of food chain material. This instrument could meet the criteria of CVR and CVI for content validity test. Moreover, the empirical validity test analysis demonstrated that the items in the instrument met outfit MNSQ and Outfit ZSTD criteria. The difference value in the item reliability and the person reliability showed a significant result, which marked the instrument developed had good item quality. The developed food chain feeding relationship instrument was able to assess students' understanding of the food chain. This three-tier test is valid and reliable for evaluating students' alternative conceptions.

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