



Middle School Students' Conceptual Understanding of Diseases: A Learning Progression Approach

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ABSTRACT

The concept of disease is taught at all levels of schooling in Indonesia, but in non-consecutive core concepts. Such a disjointed approach may affect students' understanding. Learning progression (LP) is one alternative to sequencing core ideas. This study aims to test the conceptual understanding of disease of 7th and 8th graders, and to check the validity of the LP instrument. The sample (N=296) was selected based on a selected cluster from four middle high schools in Surakarta, Indonesia. The ex post facto design with two unmodified variables, gender and grade, was applied to measure the conceptual understanding of the students. To test this, an Ordered Multiple Choice (OMC) test was conducted. Validity was measured using the Rasch model, and the students' conceptual understanding was categorised based on four levels of LP. The findings were that the instrument was valid and reliable, but lacked effectiveness in relation to difficulty level and distinguishing power. 38.75% of the students were at level 3, which is the suitable level for both grades, 27.86% were at level 4, and fewer than 20% were at levels 1 and 2. There were no differences in grade and gender. It can be concluded that the number of students with an adequate level of understanding of disease is relatively low. It is therefore recommended that the disease curriculum, as one of the life science topics, is redesigned.

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1. INTRODUCTION

Students' learning outcomes illustrate how they understand concepts. They may be influenced by many factors, such as their academic ability, background, environment, and learning processes (including models and strategies) (Avci, 2019; Botha, 2010). Effective learning can be achieved by paying attention to various factors, such as the students' character, learning objectives, learning materials, and assessments (Grösser, 2007). Effective learning must connect students' knowledge about a concept to their prior knowledge. This can be achieved if the learning processes are continuous, mutually supportive, and interrelated.

Learning Progression (LP) is a thinking framework concerning the stages of students' concept acquisition, from simple to more complex ones, over a long period (National Research Council, 2007). It outlines the level of students' conceptual understanding; the concepts that need to be understood increase in difficulty with each level. LP aims to reflect the levels of students' conceptual reasoning and understanding. It is also sometimes referred to with diverse terms, such as learning trajectory, learning activities, and learning continuity.

LP helps education experts to create appropriate curricula, learning, and assessment methods (Corcoran & Mosher, 2009). It can be utilised to evaluate students' understanding and learning outcomes (Alonzo & Gotwals, 2012).

LP has been extensively researched, notably in science, such as in the fields of genetics, natural selection, innovation, and energy. In relation to genetics, it was investigated by Duncan et al. at various levels of education. Their approach was divided into two main topics: classical genetics (Mendelian), and modern genetics (molecular). They employed an Ordered Multiple Choice (OMC) test with leveling answers (level 1 to 4 based on NRC) intended to indicate the levels of students' conceptual understanding of genetics at their specific grade level (Duncan, Rogat, & Yarden, 2009, 2016; Duncan & Choi, 2017; Duncan & Tseng, 2010). LP with regard to natural selection through formative assessment was studied by Furtak (2012) and applied to evaluate students' understanding of the topic. The development and validation of LP in the field of evolution has also been considered; for example, in relation to students' understanding of Stellar Structure and Evolution (SSE)

(Colantonio, Galano, & Leccia, 2018). Research to develop learning progression at every level of education in the topic of energy has also been conducted (Herrmann-Abell & Deboer, 2018; Jin & Anderson, 2012).

Research on LP in Indonesia has taken place, especially in the fields of mathematics and physics. In relation to mathematics, it has been developed for topics such as negative numbers and statistics (Fuadiah, 2017; Yulianti, Hartono, & Santoso, 2015). In addition, for physics various topics have been developed, such as force and motion, and normal bodies. Such research has led to LP trials (Hermita, Suhandi, Syaodih, & Samsudin, 2017; Ramalis & Efendi, 2017). However, in biological science, the approach remains uncommon.

Various topics in biology have been covered; for example, system disorder or disease. It has been covered in some chapters (chapters about body system) and discussed in relation to all grades or levels of education. Moreover, Indonesia is a country with a high rate of tropical diseases (communicable and non-communicable) and mental illnesses (Habib & Saha, 2011). The issue of disease has become even more important in the era of the Covid-19 pandemic.

In the Indonesian life science curriculum, the concepts of disease are taught from elementary to higher levels. However, document analysis of the curriculum and textbooks reveals that there is a discontinuity in the teaching disease concept (Ardiansyah, Harlita, & Ramli, 2021). In the 8th grade, students learn the concepts of diseases in relation to the digestive system, the movement and skeletal system, the circulatory system, and the excretory system. Grade 9th students also the topics of the reproductive system and genetic inheritance. Students are also taught about how to prevent and cure diseases. Learning discontinuity was found in the 7th grade topic of the classification of living beings. Students were taught about diseases caused by microbes, but the mechanisms of why and how these can cause disease are not explained (Ministry of Education, 2017).

The profile of middle school students' understanding of disease can be mapped through formative test (Cary, Wienhold, & Branchaw, 2019). This can indicate the extent to which the concept is understood by students (Herrmann-Abell & Deboer, 2018). Therefore, this study considers the conceptual understanding of disease of 7th and 8th graders, in addition to checking the validity of the instruments used.

2. MATERIALS AND METHODS

An ex post facto design with two unmodified variables was adopted, these being grade and gender, with the focus on 7th and 8th grade middle school students.

The population comprised 7th and 8th grade students at public middle schools in Surakarta, Central Java Province, Indonesia (N=18,746). The sample of 296 consisted of 156 7th graders and 140 8th graders. The confidence level of the survey was 94%, and the confidence interval was 5.65. The sample was selected from four schools (Public Junior High Schools 1, 4, 6, and 9). The schools were selected purposively based on their category (high and middle-ranking in the regional league), while the students in each selected school were selected using convenience sampling or based on the recommendations of teachers. The number of students in each school was approximately 74.

The students' conceptual understanding was measured based on the 11 items of the Ordered Multiple Choice (OMC) test, which was developed based on the framework of learning progression on disease proposed by the National Research Center of the United States in 2007 (National Research Council, 2007). The items cover the concepts of pathogens, body defence, infection, and preventive methods.

The validity of the items was analysed using the Rasch model, which included validity, reliability, difficulty level, and distinguishing power. Items are deemed valid if the MNSQ (mean square) outfit value is between 0.5 and 1.5 and the ZTSD (z-standard) outfit value between -2 to +2 (Susongko, 2016). Items are confirmed to be reliable if the values of item and person reliability are higher than 0.69. The difficulty index and distinguishing power of the item follow the categories described below.

Item difficulty in the Rasch model, according to Sumintono and Widhiarso (2015), is divided into four categories based on *measure logit* as follows:

- a. < -1 : very easy
- b. -1 to 0 : easy
- c. 0 to 1 : hard
- d. > 1 : very hard

The formula below was used to calculate the items in order to measure the students' understanding of disease:

$$H = \frac{[(4 \times \text{separation}) + 1]}{3}$$

where

H is index strata separation

3. RESULTS AND DISCUSSION INSTRUMENT VALIDITY

The validity and reliability tests concluded that the 11 OMC items were valid and reliable. The results are shown in Tables 1 and 2.

Table 1. Instrument Validity

Item number	MNSQ	ZSTD	Validity
1	1.08	1.24	Valid
2	1.02	0.35	
3	1.19	1.96	
4	0.98	-0.35	
5	1.00	0.02	
6	0.78	-2.00	
7	1.00	0.06	
8	0.68	-0.69	
9	0.98	-0.21	
10	0.99	0.04	
11	0.98	-0.26	

Table 1 shows that all 11 items have values of $0.5 < \text{MNSQ} < 1.5$ and $-2.0 < \text{ZSTD} < +2.0$, so were declared to be valid. Instrument validity was influenced by several factors, such as the instrument itself, validation administration, the scoring system, and the answers from the students (Arifin, 2009). The validity can be caused by the instrument and the answers. Sentence structure can affect students' interpretation and may cause them to choose the distractor options. Students can also choose answers simply by guessing. These factors possible affected the instrument validity.

Table 2. Instrument Reliability

Item reliability	Reliability	Person Reliability	Reliability
0.98	Excellent	0.24	Low

Instrument reliability is influenced by several factors, such as the number of items, the score distribution, and objectivity (Gronlund & Waugh, 2009). Table 2 shows that the instrument has an item reliability value of 0.98 and person reliability value of 0.24. This means the instruments have very high item reliability, but low person reliability. The reliability of the items was high because the instruments can be used on various occasions and produce consistent results.

Table 3. Analysis of Item Difficulty Level

Item No.	Logit	Category
1	0	Easy
2	0	Easy
3	-1	Easy
4	0	Easy
5	-1	Easy
6	+1	Hard
7	0	Easy
8	+3	Very difficult
9	0	Easy
10	+2	Very difficult
11	0	Easy

The instrument was also tested for its difficulty level; the results of the item analysis are shown in Table 3.

Eight of the 11 items were easy, one items were hard, and the others very difficult. Distinguishing powers were calculated with a strata separation formula. The separation of person (respondent) is 0.55, with $H = 1.07$ rounded down to 1. This indicates that the test was unable to divide the respondents. The result of the calculation show a separation of items of 7.46, with $H = 10.8$ rounded up to 11. This means the item can be divided into 11 categories. It can be concluded that the instrument have good distinguishing power for the item, but poor power for respondents.

The items were considered good if they had medium difficulty, good distinguishing power, and logic and functional distractor items (Asrul et al., 2015). If strata separation is high, the item has good distinguishing power because it can divide the respondents and item into groups. The calculation means that the research item had a different level of difficulty, but it did not target the students' level of understanding (Sabah & Hammouri, 2013).

The results of the item validity test show that the items still needed some improvements, especially in the difficulty and distinguishing power, because both categories produced results not yet optimal. Improvements need to be made in line with the requirements of good items; they should be valid, have good reliability, a moderate difficulty level, and have high distinguishing power (Arifin, 2009; Asrul, Ananda, & Rosnita, 2015; Gronlund & Waugh, 2009; Sabah & Hammouri, 2013). Gotwals and Songer (2013) state that if items have good validity and difficulty levels it means that they could provide adequate information from all those taking the test.

PROFILE OF STUDENTS' CONCEPTUAL UNDERSTANDING

The concepts related to disease are studied by grade 7 students in their first semester. They are embedded in various topics such as microorganisms and organ systems. In the second semester, they study the relationship between environmental pollution and health, which is associated with the emergence of pathogenic microorganisms in a polluted environment. For grade 8 students, the concepts related to disease are studied in the various topics concerning disorders in organ systems (locomotors, digestion, circulation, respiration, and excretion) caused by pathogens, the environment, lifestyle, or declining organ ability.

Table 4. Percentage of Students based on Grade and Gender at each LP Level

LP Level	Percentage (%)				
	Grade			Gender	
	7	8	Average	Male	Female
Level 1	15.62	16.66	17.45	14.54	15.62
Level 2	16.88	17.03	15.56	18.73	16.88
Level 3	39.72	37.88	38.48	39.41	39.72
Level 4	27.78	28.43	28.51	27.32	27.78

Table 4 shows that 39.72% of grade 7 and 37.88% of grade 8 students gave the correct answers (level 3), indicating that there was no significant difference in the number who gave the correct answers. It also shows that less than 50% of the sample were able to give the correct answers.

The significant number of students who gave incorrect answers may have been caused by several factors, one being their preconceptions gained when at elementary school. They might have learned that the diseases were caused by individual habits and the environment, thus making them choose the wrong answer choices. This is because prior knowledge obtained from previous education, experiences, and observations affects how students understand concepts (Mustika, Hala, & Aarsal, 2014; Olusegun, 2016).

Table 5. Percentages of Students' Answers to Each Level according to Gender.

No	Grade 7				Grade 8			
	Aligned level (%)	Unaligned level (%)		Aligned level (%)	Unaligned level (%)			
		Under leveled	Over leveled		Under leveled	Over leveled		
	3	1	2	4	3	1	2	4
1	48.51	1.59	2.79	47.11	30.47	0.76	4.65	64.12
2	49.88	1.20	32.55	16.37	48.76	0.00	35.28	15.96
3	68.88	15.36	15.77	0.00	72.62	17.15	10.23	0.00
4	53.93	13.36	2.19	30.52	49.24	12.34	7.41	31.01
5	55.9	4.98	27.51	11.61	57.52	5.57	22.13	14.77
6	30.49	14.51	16.78	25.57	25.92	36.53	13.80	23.76

7	40.90	52.51	0.00	6.60	38.58	54.49	1.52	5.41
8	5.58	30.77	13.22	50.42	1.35	35.28	13.91	49.46
9	38.32	10.76	0.00	50.92	33.77	9.63	1.19	55.41
10	8.76	2.79	37.34	51.11	15.80	3.63	36.26	44.32
11	34.65	18.97	36.38	9.99	42.69	7.85	40.91	8.55
Average	39.62	15.16	16.78	27.29	37.88	16.66	17.03	28.43
SD	19.32	15.20	14.68	19.76	19.75	17.73	14.50	21.91

where

Aligned level : the level of understanding that middle school students (7th and 8th graders) should have

Under leveled : the level of understanding for 3th to 6th graders

Over leveled : the level of understanding for 9th to 12th graders

Table 5 shows that 7th grade students performed at level 3 in several concepts, but that the percentage was still below 50%. The results show that three concepts were taught at level 1 (pathogens can cause disease and disease can be transmitted by patients). This was related to the level 2 concept (the body has defences against disease and pathogens, one of these being the skin) and to the level 3 concepts (a specific pathogen causes a specific disease; the body has white blood cells to fight bacteria; and disease can be caused by lifestyle and the environment). The result shows that the students' understanding was imperfect, possibly because of the lack of concept learning continuity (Code et al., 2020). Therefore, the students only understood concepts from what they learned at elementary school because they choose the answer that elementary student should have understand.

Table 5 shows that for five items the grade 7 students gave the answers other than level 3 ones. Most gave level 4 answers to three of the five items, level 1 answers for one item, and level 2 answers to the other item (Q7). The details of Q7 are shown in Table 6.

In this question, the students needed to choose option 3 (pathogens enter the body through the respiratory tract when in contact with the infected individual). However, most students chose level 1 (option 1). Option 1 covers the direct transmission of pathogens, while option 4 or level 4 answer cover the transmission of diseases related to the genetic makeup of individuals. Based on the curriculum, grade 7 students should be able to answer at level 3, because they have been taught that pathogens (viruses and bacteria) can enter the body through the respiratory tract and cause upper respiratory tract infection (Ministry of Education, 2017).

The tendency of students to give level 1 answers was because they had learned and understood that diseases can be transmitted directly from patients. They did not choose level 4 answers because genetics is not learnt until grade 9. In addition, they might not have comprehensive understanding because the concepts contained in level 3 answers were taught in the second semester of grade 7.

Most students gave level 2 answers to Q11, whereas they should have chosen option 1. However, most chose the level 2 (option 3) answer. The level 2 answer covers the concept of a virus infecting the body when its defence system is weak. The level 1 answer covers the propagation of food-borne disease, while level 3 answer cover the life cycle of viruses that occur only in living organisms.

Most students chose the level 2 answer because they have understood that a weak body defence system can cause someone to be susceptible to disease. This was learnt not only from the textbooks, but also from observation and experience. In addition, the concept of how viruses reproduce and infect other living organisms had not been learnt by the 7th grade, as it is covered in grade 9. Students had learnt about the role of viruses in causing disease, but not yet about the life cycle of a virus (Ministry of Education, 2017). Most students gave level 4 answers to Q8, Q9, and Q10.

The level 4 answer options for Q8 and Q9 were related to genetics, the immune system, and gene mutations, while those for Q10 were related to the treatment of diseases caused by viruses. Most grade 7 students chose level 4 answers to these three questions. Q8 had two level 4 answers related to the immune system and genetics. Based on the LP scheme, students should understand that the body has white blood cells as a defence against pathogens, but the learning system in Indonesia has not yet established this concept for grade 7 students. If they had chosen the answer related to the immune system, they might have understood the defence system against pathogens. This was the basis for understanding the immune system at level 4 (grade 9).

Most students also gave level 4 answers to Q9. Grade 7 students have not yet learned about genetics and gene mutations, topics which are studied by grade 9 students and expanded upon during the 12th grade. The interviews revealed the students' understanding that diseases caused by genetic factors can be inherited, which affected their choice of answers related to genetics.

It is also possible that the students simply guessed the answers. The level 4 answer to Q9 was related to the concept of genetic mutation. The choices could be answered by students if they have learned that genes can undergo changes and that these can cause diseases such as cancer. Moreover, cancer is not only caused by gene mutations, but also by unhealthy lifestyles and pathogenic infections. In addition, several factors might have influenced the students' choice of a level 4 answer to Q10, which was about medicine as treatment for diseases in relation to the phrase "prevent the development of the virus." This phrase is the key for the students to choose the level 4 answer.

For Q7, most grade 7 students chose correct level 3 answers for several concepts, but the figure was still below 50%. These concepts concerned the characteristics of pathogens that cause disease, the body's reaction to pathogenic infections, and how pathogens (i.e., viruses) infect the body. Several factors could have affected the students' answer choices, such as their prior knowledge gained during elementary school. If the learning was sustainable and continuous, it would help them to understand the concepts learned in 8th grade. This demonstrates that the learning process in Indonesia is neither sustainable nor continuous (Ministry of Education, 2017). Students could also have chosen level 4 answers based on the concepts learnt in grade 8 that related to the options. However, it is also possible that they might have simply guessed the answers. Most grade 8 students also chose other level answers to six different items; level 1 answers to two items (Q6, and Q7), the level 2 answers to one item, and level 4 answers in the case of four students.

Grade 8 students should be able to answer precisely at level 3. As explained before, they have been taught about health disorders in the human organ system (locomotors, digestion, circulation, respiration, and excretion) caused by pathogens, the environment, lifestyle, or declining organ functions (Ministry of Education, 2018). The level 3 answer to Q6 included the concept of an unhealthy lifestyle causing disease. For Q7, the level 3 answer covered the concept of pathogens (i.e. viruses) being able to enter the body through the respiratory system and cause illness. Both concepts are learnt by 7th and 8th graders. However, most students gave the level 1 answer.

There are two reasons why they chose the level 1 answer. First, the learning process, which does not teach mutually sustainable concepts in a continuum. Second, the students may have ignored the process. Discontinuous concept learning can cause students' understanding to be interrupted, so they only achieve imperfect knowledge (Code et al., 2020). If they do not pay attention during the learning process, they will not understand the topics.

Most students gave the level 4 answers to Q1, Q8, Q9, and Q10. This may have been due to several factors, including prior knowledge, guessing the answers, and keywords for the answers. The level 3 answer to Q1 was that viruses and bacteria that enter the body can cause diseases. However, most students chose the level 4 answer, which covers the concept of the immune system which has not been learnt by 7th and 8th grade students. However, in these grades they have learnt about viruses and bacteria that can cause disease in humans, in both semesters 1 and 2. They have learnt the concepts covered by the level 3 answer, so they were expected to choose this answer. This result shows most students did not have a comprehensive understanding of what they had learnt in grades 7 and 8.

The question items were developed based on LP concepts of disease that must be understood by the students. These include disease-causing pathogens, infectious mechanisms, the body's reaction to infection, and prevention efforts against infection. Those concepts are disease concepts that must be understood by junior high school students. Cordell et al. (2017) showed that junior high school students must understand the causes, spread, and prevention of disease. Barber and Stark (2015) also state that junior high school students have been taught about the spread and sources of disease through stimulation to improve their understanding.

The results show that in both grades 7 and 8 the students' knowledge of disease was not at the expected level 3, as demonstrated by the fact that the percentage of students who gave the level 3 answers did not reach 50%. Therefore, students in both grades 7 and 8 have a conceptual understanding which is unaligned with the expected level, as based on the LP scheme proposed by the NRC (National Research Council, 2007). The results show that discontinuous concepts could mean students' understanding of them that does not match the expected level. Concept understanding not in accordance with the expected level indicates that the students'

understanding was relatively low (Hadenfeldt et al., 2016). The solution recommended is to apply LP to biological learning, as based research that has shown that LP is able to improve students' understanding of biology concepts (Duncan et al., 2016; Elmesky, 2013; Neumann et al., 2013; Tibell & Harms, 2017).

4. CONCLUSION

The results of the study show that all the instrument items were valid, with very high item reliability, but low person reliability. In terms of difficulty, eight items were easy, while the other three were hard or very hard. The items also had good distinguishing power. The item validity test also showed that the items still require development with regard to difficulty and distinguishing power. The results of the analysis of the knowledge profiles of the 7th and 8th grade students show that their understanding of disease topics is unaligned with their expected level, based on the learning progression scheme of the NRC.

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