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Analysis of Competency Level for Wave Science in General Physics-Based on Literacy Science in PISA

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Abstract. PISA competency framework has been gained global recognition from 2006 and was developed until the latest version in 2015. PISA competency emphasis is classified into three competencies standard, such as explaining scientific phenomena, evaluating and designing scientific inquiry, and interpreting scientific data and evidence, finally, summarizing research findings. All of the PISA's standard competency is reflected in each of the three types of knowledge that consist of content knowledge, procedural knowledge and epistemic knowledge. PISA science assessment is based on science literacy. This article will analyze the three competencies of PISA science literacy determined by each knowledge in basic physics topics: wave. Furthermore, the subject matter refers to wave phenomenon, types of wave, the magnitude, the formula, superposition of wave, reflection and refraction, resonance, and the energy of wave.

1. Introduction

Indonesia is one of emerging and developing countries according to ground domestic product (GDP) per capita [1]. Indonesia's GDP expanded by an average of more than 1 trillion U.S dollar, however, Indonesia's economy still grew less than expected in the ASEAN countries from 2008 to 2018 [2] [3]. Indonesia's GDP dividing by its population is an estimate of how much income, on average, the economy produces per person (per capita) per year. In other words, GDP per capita is a measure of a nation's standard of living. Good education chances to get the employment opportunities which help to maintain the quality of living standard. A good education is directly proportional along with the human capital it generates. A country can be defined globally competitive based on their educational system.

In recent years, Indonesia has adopted curriculum learning referring to Indonesian National Qualification Framework (KKNI) as Presidential Regulation Number 8 of 2012, and Law Number 12 of 2012 concerning Higher Education [4]. KKNI is a national qualification framework to measure the achievement of the educational process as a basis for recognition of one's learning outcomes [5] [6]. This framework collaborates research activities and learning innovations. However, there are several problems still related to system quality and access as well as the even distribution of well-trained teachers. According to the Director General of Primary Education at the Ministry of Education and Culture, many schools in Indonesia face a serious shortage of teachers and are estimated to reach 140,000 teachers [7]. This phenomenon is frequently a reflection of the limitations of the education system in Indonesia. Consequently, Indonesia does not have proper education, it may be left behind by other countries.



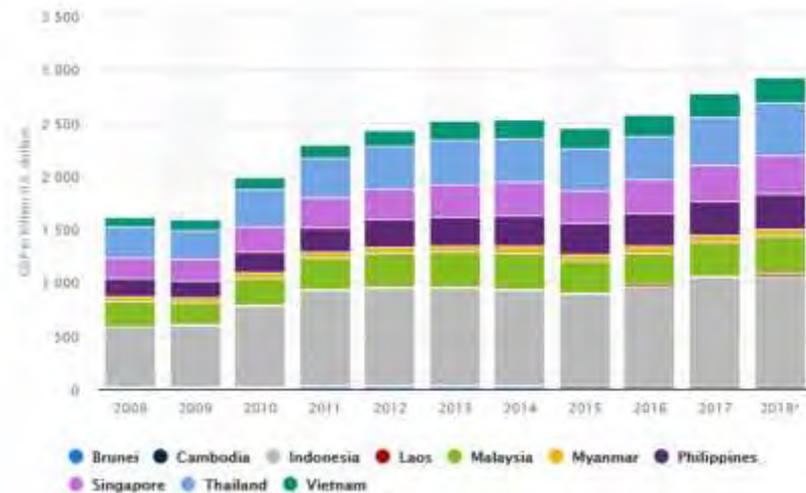


Figure 1. Gross domestic product (GDP) of the ASEAN countries from 2008 to 2018 (in billion U.S. dollars). Source: Plecher, 2019

The latest Human Development Index (HDI) shows Indonesia ranked 121st out of 185 countries, with an HDI of .629 that means Indonesia is ranked lower than two of its neighbouring ASEAN countries, Malaysia (64th) and Singapore (18th) [8]. The average score for the region was 0.683 [9]. To increasing the rate of HDI and GDP incomes, Indonesia is necessary to prioritize the acceleration of the development of the educational system [10]. Reaching the goal of the accelerating development on the educational system implies an international standard in the worldwide study, also known as PISA. The Program for International Student Assessment (PISA) deducted by The Organisation for Economic Co-operation and Development (OECD) in more than 70 nations of students [11]. Indonesian educational system adopts PISA to evaluate students’ knowledge and skill.

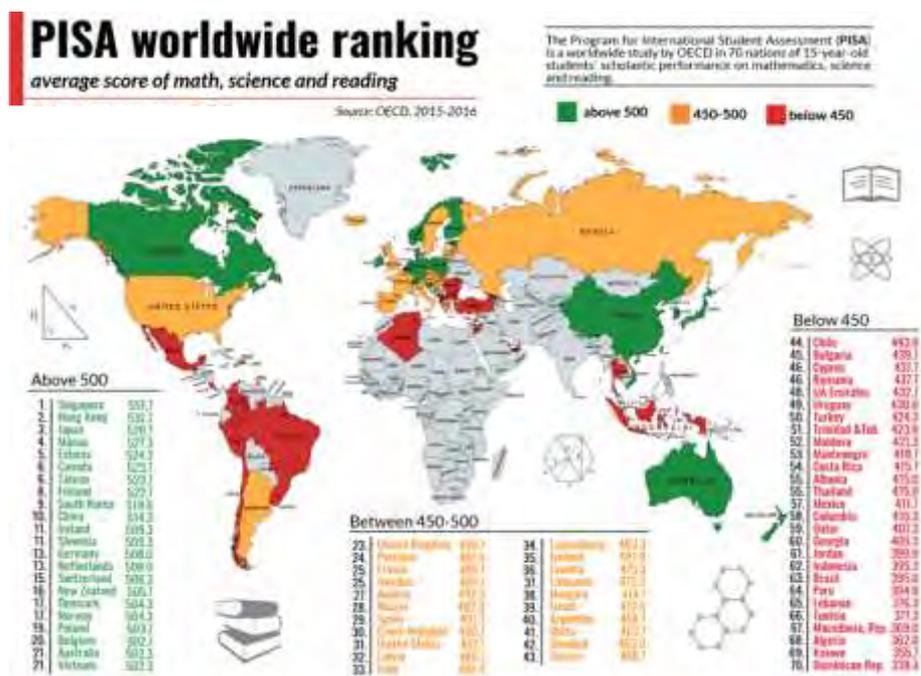


Figure 2. PISA worldwide ranking from 2015 – 2016. Source: OECD, 2016 [12]

PISA curriculum leads us to propose innovative learning solutions for students and teachers. As expected, the teacher will be advance in basic physics material (focus on wave topics) based on science literacy PISA.

2. Literacy Science in PISA

Literacy science PISA prepares students with a solid foundation in scientific knowledge and the scientific method and targets students to pursue their careers in revolutionizing and futuristic technology in fields such as education, medicine, forensics, aeronautics, and pharmaceutical research [13]. Building a strong foundation of basic scientific knowledge is required for student even they do not discuss and decide their future jobs. Students who attend school are also taught the scientific method to develop critical thinking to facing off the most concerning world issues. The scientific literacy PISA has been developed from 2006 to the latest in 2015 which consists of three competency standards,

KKNI competency standard applies the cognitive knowledge developing rational abilities (reason). The cognitive knowledge decides into six-compliments with each components knowledge (C1), comprehension (C2), application (C3), analysis (C4), synthesis (C5), and evaluation (C6). This framework calls Bloom's taxonomy [14]. However, the overall PISA competency standard applies three including (1) Explain scientific phenomena, (2) Evaluate and design scientific inquiry, and (3) Interpret scientific data and evidence and summarize the results of science for each types of knowledge: content knowledge, procedural knowledge and epistemic knowledge [15] [16].

1. Content knowledge includes factual knowledge and basic concepts of science and its guarantee the successful application. Factual knowledge is basic elements of scientific facts that occur in detail and systematically. Conceptual knowledge represents the idea or understanding of a scientific concept that is quoted from concrete (factual) events.
2. Procedural knowledge includes the concepts of independent variables, dependent variables and control variables, the concepts of quantitative and qualitative measurements (observation), scales, single and repeated measurements, the use of data repetition (graphs, tables, diagrams, variable setting strategies, designing experiments).
3. Epistemic knowledge includes topics about how to construct and see the most influential parts of science internally and the role of science externally. Indicator trends show the level of change in achievement and distribution of achievement, the relationship between student levels, school levels and the background of the system for each type of level and achievement results (epistemic knowledge).

3. Wave Science

In general, the types of wave phenomena belong to the materials of basic-physics concerning sound waves, light waves, waves on a rope, waves on water, radio waves and others. To realize the concept of wave, let's look at waves on the surface of the water. When we drop a rock on the surface of a calm pool water there will be symmetrical ripples as the water molecules oscillate in a small circle. This oscillation forms wave crests and wave troughs. Another example is transverse waves on a rope. When we tie a rope and then make a perpendicular motion one end of the rope up and down. So, there will produce a wave pattern. When we look at the points on the medium, we will find that the propagation is just oscillating around the balance point. From these two observations, we can make a general definition of the wave. Mechanical waves are mechanical waves propagation energy in the medium without medium displacement. On the other hand, electromagnetic waves are electromagnetic waves propagation energy without a medium [17].

4. Competency level for wave topics

Literacy science PISA on wave material competencies consist of several topics such as wave phenomena and properties, components and parameters of waves and refer to below table.

Table 1. Competencies based on Pisa literacy for wave topics phenomena and properties

Competency Level	Indicators
Wave phenomena and properties	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Explain the difference of wave phenomena due to events of reflection, refraction, dispersion, interference, diffraction, resonance and polarization of waves.) Explain the difference between mechanical and electromagnetic waves through real-case examples.) Explain the difference between transversal and longitudinal waves through real-case examples.) Explain the difference between standing and stationary waves through real-case examples
Evaluating and designing scientific enquiry	Measure the depth of the ocean with sound wave reflection applications.
Interpreting data and evidence scientifically	The difference between the echo phenomena with different sound propagation data.
WaveParameters	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Analyze wave phenomena related to wave deviation and amplitude.) Analyze wave phenomena related to wave velocity, frequency and wavelength.
Evaluating and designing scientific enquiry	Analyze wave phenomena related to wave velocity, frequency and wavelength through experiments and measurement of wave quantities.
Interpreting data and evidence scientifically	Interpreting the properties of wave velocity, frequencies and wavelengths based on the associated wave magnitude data.
Wave Quantities	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Analyzing the wave quantities associated with the wave function.) Analyzing the wave quantities associated with the wave's general equation.
Evaluating and designing scientific enquiry	<ul style="list-style-type: none">) Measuring wave propagation in a string through experiments.) Measuring wave propagation fast on solid media through experiments.) Measuring wave velocity on fluid medium through experiments.) Measuring sound propagation quickly through experiments
Interpreting data and evidence scientifically	Interpret data related to wave velocity.
Reflection, refraction and dispersion of waves	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Explain the phenomena associated with wave reflection.) Explain the phenomena associated with wave refraction.) Explain the phenomena associated with wave dispersion

Evaluating and designing scientific enquiry	<ul style="list-style-type: none">) Test the concept of wave reflection through experiments.) Test the concept of wave refraction through experimentation.) Test the phenomenon of wave dispersion through experiments
Interpreting data and evidence scientifically	<ul style="list-style-type: none">) Interpret data related to wave reflection.) Interpret data related to wave refraction.) Interpret data related to wave dispersion.
Wave resonance	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Explain the phenomenon of wave resonance in swings.) Explain the phenomenon of wave resonance in the air column.) Explain the phenomenon of wave resonance in a string.
Evaluating and designing scientific enquiry	Test the phenomenon of sound wave resonance through experiments.
Interpreting data and evidence scientifically	Interpret frequency magnitude related data on sound wave resonance.
Interference, diffraction and wave polarization.	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Explain the phenomena associated with wave interference.) Explain the phenomena associated with wave diffraction.) Explain the phenomena associated with wave polarization.
Evaluating and designing scientific enquiry	<ul style="list-style-type: none">) Test the phenomenon of wave interference through experiments.) Test the wave diffraction phenomenon through experiments.) Test the phenomenon of wave polarization through experiments.
Interpreting data and evidence scientifically	<ul style="list-style-type: none">) Interpret data related to wave interference) Interpret data related to wave diffraction.) Interpret data related to wave polarization.
Energy and Wave Intensity	
Explaining phenomena scientifically	<ul style="list-style-type: none">) Explain the relation of wave energy to the amplitude and frequency of the wave.) Explain phenomena related to sound wave intensity.
Evaluating and designing scientific enquiry	<ul style="list-style-type: none">) Measuring wave energy through experiments.) Measuring the level of sound wave intensity through experiments.
Interpreting data and evidence scientifically	<ul style="list-style-type: none">) Interpret data related to wave energy.) Interpret data related to sound wave intensity levels.

5. Conclusions

This research is designed the implementation of PISA competency level for wave science in general physics targets every student to have high-level comprehension skill. The indicators of competency level help students and teachers to apply their wave knowledge to solve problems set in real-world contexts. This is shown by students having the ability to explain the phenomenon, evaluate and design, till the interpreting data and evidence. The curriculum is also focused on teaching students practical skills that will help them applied problems in the real world. So, students find their definite effort to pursue their future careers in revolutionizing and futuristic technology in fields related to science and technology in wave technology.

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Acknowledgments

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