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Cognitive Process Analysis of PISA, TIMSS, and UN Science Items Based on Revised Bloom Taxonomy

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It has been conducted the cognitive process analysis of science items of the Program for International Student Assessment (PISA) 2006, Trends in International Mathematics and Science Study (TIMSS) 2007, and National Examination (Ujian Nasional/UN) academic year 2012/2013. The cognitive process, according to revised Bloom's taxonomy, that is remember, understand, apply, analyze, evaluate, and create. The analysis result showed the comparison among PISA, TIMSS, and UN in measuring the high cognitive process (analyzing, evaluating, and creating) is 6:3:2 respectively. The highest percentage of PISA items measured level cognitive process of analyzing, evaluating, and creating; TIMSS items measured level cognitive process of applying; and UN items measured level cognitive process of remembering and understanding.

Keywords: Cognitive Process, PISA, TIMSS, UN.

1. INTRODUCTION

Anderson and Krathwol[2] have revised the Bloom's taxonomy by completing the highest cognitive level of evaluating becoming creating. Besides increasing the cognitive level, the use of verbs in the new taxonomy implies the importance of cognitive process. Thus, in the learning process is not only focuses on the learning result but also the learning process. The cognitive process dimensions in the new taxonomy are: remember, understand, apply, analyze, evaluate and create. The last three cognitive processes, according to Anderson and Krathwol, are the higher order thinking skills.

Higher-order thinking is the ability to think logically, critically, creatively, and demonstrate problem-solving skills.[5] Higher-order thinking skills is not only in the classroom context, but also must be implemented in daily life.

Zohar and Dori[9] stated that the education must be guided to the achievement of the higher order thinking skills. Moreover, if we give the attention to the development of rapid technology and development of the knowledge, psychology and the transformation of culture's value. Thus, the education, especially in learning, must develop the students' high thinking order. Every schools must develop the higher order thinking skills to prepare their students for effective performance and meet the employers' expectations.[8]

There are some interesting phenomenon if we analyze the result of the students' achievements in Indonesia. Why do the Indonesian students put in the low group ranking in the international study? For example, in the study of TIMSS (Trends in Mathematics and Science Study) 2011, the Indonesian students were in 40th out of 42 countries and in 64th out of 65 countries in the PISA (Program for International Student Assessment) study 2012. However, in the National Examination, the graduates' total of Senior High School students reached 99.04%.

It needs the analysis of cognitive process that is measured by three assessment above. This paper reports the result of the research about the analysis of cognitive process measured by science items of the PISA, TIMSS, and national examination study based on revised Bloom taxonomy.

2. METHODS

This research is a explorative-descriptive research that gather information and analyze in depth, then describe the results found in a comprehensive manner with regard to the level of cognitive processes that are measured by the items of science in PISA, TIMSS, and the UN.

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Items in PISA, TIMSS, and the UN analyzed are the items that have been released and can be downloaded for free on the official pages. In this study, we used PISA 2006, TIMSS 2007, and the UN year 2012/2013.

The research steps outlined are shown in the table below.

No	Activity	Result/product
1	Materials and references	Comprehensive study on cognitive processes according to the revised bloom's taxonomy and its indicators Synchronized indicator of cognitive processes with the assessment framework PISA, TIMSS, and the UN.
2	Cognitive process analysis	The results of the cognitive analysis are include remember (C1), understand (C2), apply (C3), analyze (C4), evaluate (C5), and create (C6) which measured by PISA, TIMSS, and the UN items in the field of science (Physics—Earth Science, Biology, and Chemistry).
3	Result validation	The comprehensive study, the results of synchronization, and the results of cognitive processes analysis are reviewed and validated by the experts through a focused-group discussion mechanism (FGD).
4	The formulation of research found, advice, and recommendation	It is got the formulation of research result conclusion, advice for further research, and recommendation to make policy.

3. RESULTS AND DISCUSSION

The following are the analysis results of the cognitive processes that are measured by items of PISA, TIMSS, and the UN based on Bloom's taxonomy.

3.1. PISA

The PISA items is selected in 2006, because of its focus on science. Number of the released items of PISA 2006 was 76 items, with the composition and analytical results are shown in Table I.

3.2. TIMSS

The TIMSS items that is analyzed was the released items of TIMSS in 2007 that is amounted to 84 items, with the composition and analytical results is shown in Table II.

Table I. The result analysis of cognitive process in PISA items.

No	Cognitive process	Physics earth science	Chemistry	Biology	Total	%
1	Knowing	–	–	–	–	–
2	Understanding	6	4	13	23	30,3
3	Applying	2	7	2	11	14,5
4	Analyzing	6	2	12	20	26,3
5	Evaluating	3	1	17	21	27,6
3	Creating	–	–	1	1	1,3
	Total items	17	14	45	76	

Table II. The result analysis of cognitive process in TIMSS items.

No	Cognitive process	Physics earth science	Chemistry	Biology	Total	%
1	Knowing	4	4	7	15	17,9
2	Understanding	10	3	9	22	26,2
3	Applying	17	3	7	27	32,1
4	Analyzing	7	3	3	13	15,5
5	Evaluating	2	2	3	7	8,3
3	Creating	–	–	–	–	–
	Total items	40	16	29	84	

Table III. The result analysis of cognitive process in UN items.

No	Cognitive process	Physics earth science	Chemistry	Biology	Total	%
1	Knowing	1	1	9	11	27,5
2	Understanding	3	3	7	13	32,5
3	Applying	7	1	1	9	22,5
4	Analyzing	6	1	–	7	17,5
5	Evaluating	–	–	–	–	–
3	Creating	–	–	–	–	–
	Total items	17	6	17	40	

3.3. National Examination (UN)

The items of IPA SMP Year 2012/2013 consists of 40 multiple choice items. The analysis results of the cognitive processes and its composition can be seen in Table III.

Based on the analysis above if it is compared with the whole number of items of science PISA, TIMSS, and the UN, and based on cognitive processes is obtained the graph below.

Based on Figure 1, the items of PISA 2006 don't measure cognitive processes of remembering (C1). Although in a small percentage, there are PISA items which measure cognitive process of creating (C6). Approximately 55% the PISA items measure the high cognitive processes (C4–C6), the remaining measure cognitive processes of understanding and applying. The PISA question has the highest percentage in the cognitive processes C4 (analyzing) and C5 (evaluating) if it is compared with the TIMSS and the UN questions.

Items of TIMSS has the highest percentage if it is compared with PISA and UN items, about 32%, which measures

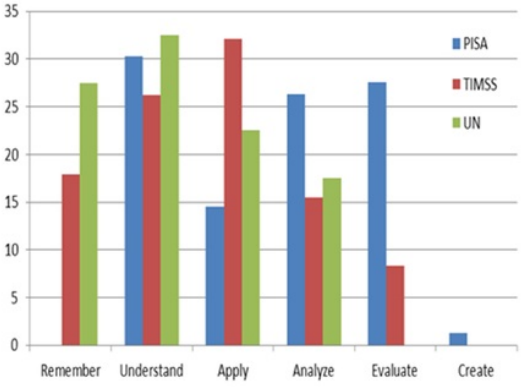
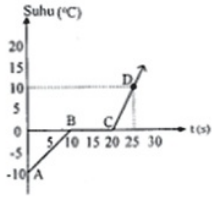


Fig. 1. The comparison of cognitive processes on the PISA, TIMSS, and the UN of science items.

4. Berdasarkan grafik di samping banyaknya kalor yang dibutuhkan 3 kg es dalam proses dari A–B–C adalah .... (kalor jenis es = 2.100 J/kg°C, kalor lebur es = 336.000 J/kg)
   A. 630 kJ
   B. 819 kJ
   C. 1071 kJ ✓
   D. 3276 kJ



5. Jika massa benda sama, maka benda yang mempunyai percepatan yang terbesar adalah ....

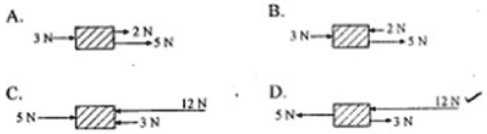


Fig. 2. Samples items of UN 2012/2013.

cognitive processes C3 (applying). Only about 25% of TIMSS items, which measures high cognitive processing C4 (analyzing) and C5 (evaluating). None of TIMSS items measures C6 (creating). Approximately 75% of TIMSS items measures low cognitive processes, they are C1 (remembering), C2 (remembering), and C3.

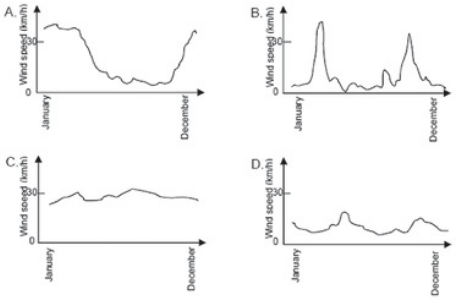
The UN items has the highest percentage if it is compared with PISA and TIMSS items in measuring cognitive process

Many people believe that wind should replace oil and coal as a source of energy for producing electricity. The structures in the picture are windmills with blades that are rotated by the wind. These rotations cause electricity to be produced by generators that are turned by the windmills.

A wind farm

Question 1: WIND FARMS S529Q01

The graphs below show the average wind speeds in four different places throughout a year. Which one of the graphs indicates the most appropriate place to establish a wind farm for generating electricity?

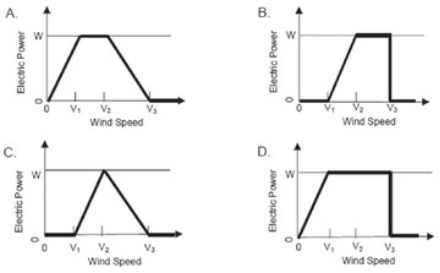


Question 2: WIND FARMS S529Q02

The stronger the wind, the faster the windmill blades rotate and the greater the electric power output. However, there is not a direct relationship between wind speed and electric power in a real setting. Below are four working conditions of electricity generation in a real wind farm.

- The windmill blades start rotating when the wind speed reaches V_1.
- The electric power output reaches a maximum (W) when the wind speed is V_2.
- For safety reasons, the blades are prevented from rotating faster than they do when the wind speed is V_2.
- The blades stop rotating when the wind speed reaches V_3.

Which one of the following graphs best represents the relationship between wind speed and electric power output under these working conditions?



Question 4: WIND FARMS S529Q04 – 0 1 2 9

Describe one specific advantage, and one specific disadvantage, of using wind to generate electricity compared with using fossil fuels like coal and oil.

An advantage .....

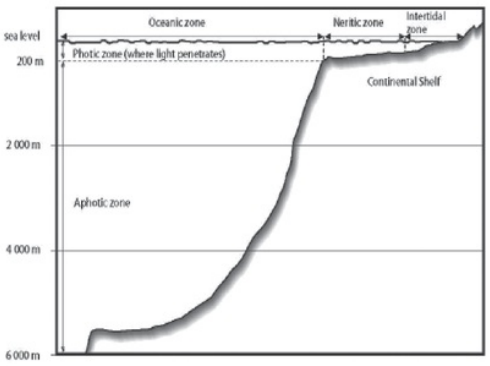
.....

A disadvantage .....

.....

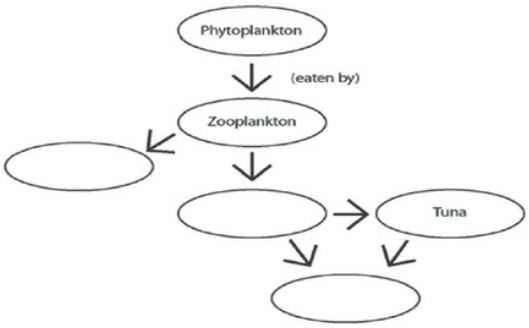
Fig. 3. Samples items of PISA 2006.

The following diagram shows a cross-section through an ocean. A number of organisms (plants and animals) live in the different regions of the ocean and depend on one another and on the Sun for survival.



A. Complete the food web on the chart below to include all the organisms listed in the table. Write the name of one organism in each circle.

The information given about each organism will help you. Three organisms have been placed on the chart for you. The arrows show the direction that energy flows through the food web.



B. One year tuna becomes scarce because of over-fishing. State what is most likely to happen to the population of sharks and explain your answer.

Look at the list of organisms (plants and animals) below. They all live in the Neritic Zone.

Organism	Description
Phytoplankton	Microscopic plants that photosynthesize
Zooplankton	Microscopic animals that feed on phytoplankton
Tuna	Medium sized fish that feeds on small fish
Herring	Small fish that feeds on zooplankton
Shark	Large fish that feeds on other fish
Whale	Large mammal that feeds on zooplankton

Fig. 4. Samples items of TIMSS 2007.

C1 (remembering) and C2 (understanding). The UN items measures cognitive process highest in analyzing level (C4). None of the UN items of IPA SMP year 2012/2013 measures the cognitive processes C5 (evaluating) and C6 (creating).

Based on the comparison above, it can be concluded that the PISA items measure the cognitive process highest level compared to the TIMSS and UN items. If it is formulated the ratio of items than measures the low (C1–C3) and high (C4–C6) cognitive processes, in PISA, TIMSS, and UN items respectively about 6:4; 3:7; and 2:8. If according to Anderson and Krathwohl, C4–C6 is to measure the ability to think critically, it means the amount of PISA items that measure the critics thinking ability are about doubled compared to the TIMSS items, and are about three times compared to the UN items. The following are presented the samples items of UN, PISA, and TIMSS.

Based on the samples items of UN, PISA, and TIMSS above, when we link it to the context of everyday life or real life, PISA and TIMSS items also more contextual, complex, and real than UN items. The real life contexts as on PISA and TIMSS items is very important for the development of higher level thinking skills as stated by Wheeler and Haertel in Forster.[3] They state that the high level thinking skills requires two types of contexts, the first one: the context of problem-solving and decision-making in everyday life, and the second: the context of higher mental processes, for example in comparing, evaluating, performing inference and decision making.

Contextual item, like the sample of PISA item above, must be focused in teaching and assessing to develop literacy. Kelley[4] stated that teaching engineering design will produce technological problem solvers who have the ability to properly manage an ill-defined problem and develop viable solutions. In the 21st century, the ...ious instructional hypermedia systems must be improved too to increase the educational impact of these systems and avoid any learning inhibitors to arise.[1]

4. CONCLUSION

Based on the results and the discussion above, it can be concluded that the comparison of PISA, TIMSS, and the UN items in measuring the high cognitive processes (analyzing, evaluating, and creating) respectively is 6:3:2. The percentage of the PISA items measures cognitive processes highest of analyzing, evaluating, and creating if it is compared with the TIMSS and UN items. The highest percentage of TIMSS items measures cognitive processes of applying if it is compared with PISA and UN problem. The highest percentage of the National Examination (UN) measures the cognitive process of remembering and understanding if it is compared with PISA and TIMSS items.

It is necessary to improve the quality of the national examination items, in order to be able measuring the higher cognitive processes. That efforts must also be accompanied by increasing the quality of learning that provides the wide space for students to

develop the higher-level of thinking. Without efforts to improve learning seriously we certainly cannot expect the increasing of rank on the results of TIMSS and PISA, because the items empirically measure the ability of high-level thinking.

References and Notes

1. E. M. Alkhalifa, *Educational Technology and Society* 8, 40 **(2005)**.
2. L. W. Anderson and D. R. Krathwohl (eds.), A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Longman, New York **(2001)**.
3. M. Forster, *Research Development* 11 **(2004)**.
4. R. Kelley, *Journal of Technology Education* 19, 50 **(2008)**.
5. F. J. King, L. Goodson, and F. Rohani, Higher Order Thinking Skills: Definition, Teaching Strategies, and Assessment, Center for Advancement of Learning d Assessment **(2014)**.
6. I. V. S. Mullis, M. O. Martin, G. J. Ruddock, C. Y. O'Sullivan, A. Arora, and E. dan Erberber, TIMSS 2007 Assessment Frameworks, TIMSS and PIRLS ternational Study Center, Boston College, Chestnut Hill **(2005)**.
7. OECD, Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006, OECD, Paris **(2006)**.
8. D. Shukla and A. P. Dungsungnoen, *Journal of Education and Practice* 7, 211 6).
9. A. Zohar and Y. J. Dori, *The Journal of the Learning Sciences* 12, 145 **(2003)**.

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