Analysis of Student Higher Order Thinking Skills in Solving Physics Examination

Elyana, NurIslami, Yennita, Fakhruddin
Physics Education, FKIP, University of Riau,
Jl. HR. Soebrantas, Simpangbaru, 28293, Pekanbaru, Indonesia
Email: elyanayana07@gmail.com

Abstract: Analysis Of Student Higher Order Thinking Skills In Solving Physics Examination. This study aims to determine the percentage of national physics exam questions that were categorized Higher Order Thinking Skills (HOTS) and to know the ability of high-level thinking students. The method that was used in this research is descriptive research. The subjects of this study are 129 students of MAN 2 Model Pekanbaru. The data obtained in this study was percentage of Physics 2016 with HOTS category that was analyzed using indicator problems according to Thomas & Thorne is 15%, and data analysis of students' high thinking ability on the matter of national exam physics obtained through student answers in answering the questions with the percentage of students able to answer 46%. Based on the data analysis can be concluded that the national exam of physics is able to measure the ability to think high-level students who average were categorized as low average.

Keywords: Higher Order Thinking Skills, HOTS Students, National Physical Exam

1. Introductions

In order to prepare graduates for education to enter the era of globalization which is full of challenges and uncertainties, education is needed that is designed based on real needs in the field. The birth of the 2013 curriculum addresses the challenges and shifts in the development paradigm from the 20th century to the 21st century. For this purpose, the Government arranged the curriculum. Assessment models in the 2013 Curriculum adapt international standard assessment models that help students to improve their Higher Order Thinking Skills, so that they can encourage students to think broadly and deeply about the subject matter (Setyorini, 2015: 152)

Through physics learning, students are expected to develop themselves in thinking. Students are required not only to have low-level thinking skills (lower order thinking), but to the ability to think higher (higher order thinking) (Istiyono, 2013: 2). With regard to these higher-order thinking abilities, the facts show that Indonesian physics achievements are ranked 50 out of 53 countries (TIMSS and TIMSS Advanced, 2016), while for PISA reported by the Organization for Economic Operation and Development (OECD) are at ranked 62 of 70 countries (Sumarni, 2013: 69). Thus, physics achievements that demand high-level thinking skills of Indonesian high school students, on the international stage are low. Schools should start planting HOTS to meet the demands of the 21st century. This is in accordance with the characteristics of 21st century community skills according to the partnership of 21st century skills which identifies that students in the 21st century must be able to develop competitive skills needed in the 21st century focused on the development of HOTS (Diptoadi, 1999: 164) .Higher Order Thinking Skill or high-level thinking is the concept of education reform based on taxonomic learning such as Bloom's taxonomy. In Bloom's Taxonomy, skills that involve analysis, evaluation, and synthesis are considered to be a higher order that requires learning methods of knowledge of facts and concepts (Fahmi, 2014: 39). Students are trained to be able to think logically, consistently and systematically, using HOTS capacities. To measure the high-level ability of students, it is needed an assessment that is expected to encourage the improvement of higher-order thinking skills, increase creativity, and develop the independence of students to solve problems (Directorate of High School Development 2015). By the Indonesian government, the National Examination (UN) is still maintained as a form of final assessment at an educational institution level to determine students' graduation. Based on Ramadhan & Wasis research (2013: 22) and Syahida & Irawan (2015: 77) the National Physics Examination can measure students' high-level thinking skills if the percentage of HOTS questions ranges from 7.5% - 15%.

This study aims to determine the percentage of HOTS High School Physics UN 2016 questions analyzed based on the characteristics of the problem according to Thomas & Thorne (2010) which suggests that Higher Order Thinking Skill is a higher level of thinking than memorizing facts or saying something back heard and known. High-level thinking requires students to do things with facts. Learners must understand, conclude, link facts with other facts and concepts, categorize, manipulate, unify in new forms, and apply them like finding new solutions to newly encountered problems. This study also aims to determine the high-level thinking skills of MAN 2 Model Pekanbaru students in completing the Physics UN.

2. Methodology

This research is a descriptive study conducted in November 2016 - January 2017. The used subjects were 129 students of MAN 2 Model Pekanbaru class XII using the 2015/2016 High School Physics UN questions consisting of 40 questions. Of the 5 available UN question packages, only 1 question package is to be analyzed, namely the question package with the U-D1515 / 2016 code.

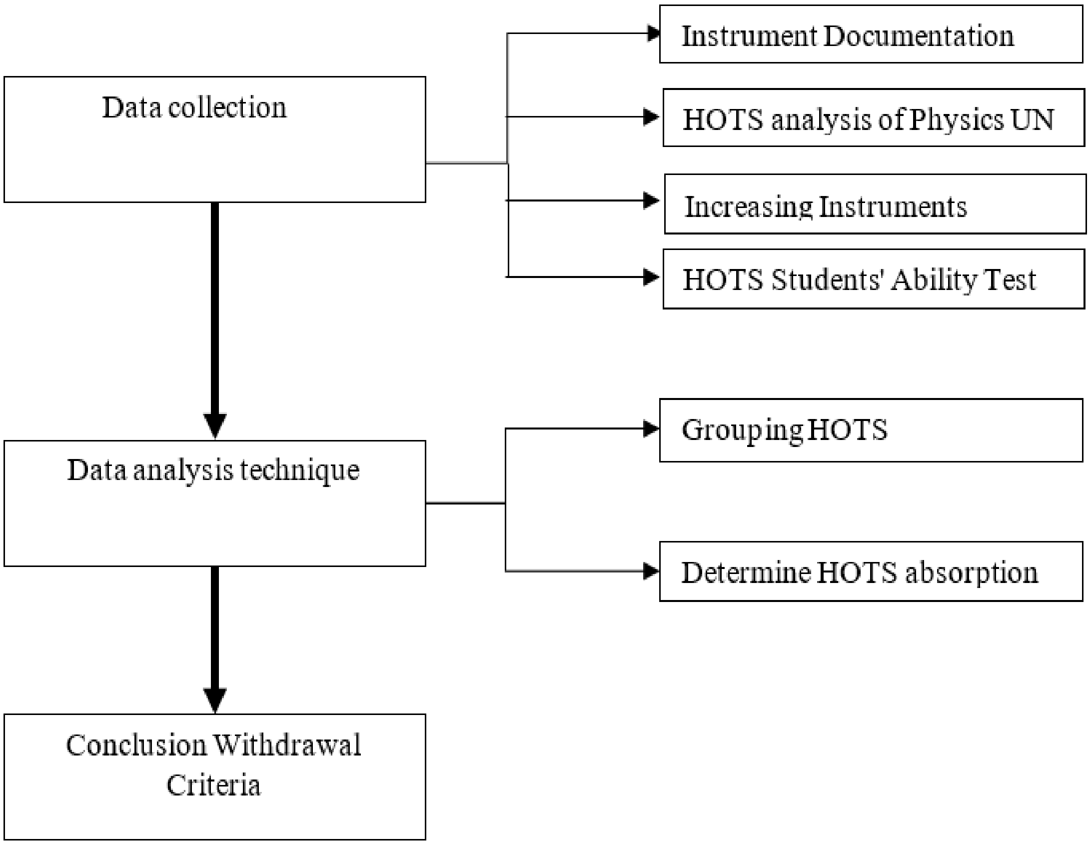

Figure 1. Research method

1. At the data collection stage, documentation was made by photocopying research instruments and analyzing HOTS based on HOTS indicators according to Thomas & Thorne (2010) on the physics UN questions to be used. After being analyzed, the questions were multiplied into several packages. Then a test was conducted to measure the ability of students of MAN 2 Model Pekanbaru,

2. In the next stage, the data were analyzed using descriptive techniques. The steps of data analysis in this study are:

a. Grouping items on the National Physics / High School National Examination level that are included in the HOTS category.

$$\%\ HOTS = \frac{the\ number\ of\ questions\ HOTS}{total\ questions}\ x\ 100\%$$

b. Determine the HOTS absorption capacity of students in the completion of the National Physics Examination level for high school / MAN.

$$\% \, HOTS \, Absorption \, Absorption = \frac{The \, Value \, of \, All \, Students \, Absorbs \, HOTS}{number \, of \, students \, x \, number \, of \, ideal \, scores} x \, 100\%$$

At the conclusion stage, the 2015/2016 National Physics Physics Exam Question was declared able to measure HOTS students if the percentage of UN questions classified as HOTS was in the range of 7.5% - 15%. This is supported by the research of Ramadhan & Wasis (2013: 22) and Syahida & Irawan (2015: 77) which states that the percentage of HOTS questions in the National Examinations both at the high school and junior high schools ranges from 7.5% - 15%. The following criteria are the categories of student absorption in the completion of the National Physics Examination level for high school / MA which includes HOTS:

Table 3.2. Criteria for Student HOTS Absorption Category

Absorption interval (%)	Absorption category
$85 \leq X \leq 100$	Very good
$70 \leq X < 85$	good
$50 \leq X < 70$	Good enough
$0 \leq X < 50$	Not so good

Source: (Ministry of National Education, 2007)

3. Results And Discussion

Percentage of 2016 HOTS UN Physics Questions

The question was analyzed based on criteria according to Thomas & Thorne (2010) which states that HOTS is a higher level of thinking than memorizing facts or saying something that is heard and known. Higher-order thinking skills occur when students find information and generate ideas and use them to solve complex problems (Yee, M.H, 2011). HOTS requires students to do something with facts. Learners must understand, conclude, link facts with other facts and concepts, categorize, manipulate, unify in new forms, and apply them like finding new solutions to newly encountered problems. This theory is reinforced by the research of Nursaila & Farida (2015: 20) that HOTS is the ability to analyze data into components and look for relationships between components.

In measuring students 'high-level thinking skills, a question is needed with indicators that meet the criteria in measuring students' high-level thinking skills. In this study, the question indicator was made based on HOTS criteria according to Thomas & Thorne (2010) which is to conclude and use facts consisting of 4 questions with irregularly moving straight motion material (GLBB), expansion of substances, determining the center of gravity, and radioactive and

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concluding facts and linking concepts consisting of 2 questions with impulse and momentum material and straight-line motion changing irregularly. Six questions were presented which emphasized understanding in concluding facts from pictures and stories and using the facts obtained in solving problems in the problem. Through Physics UN questions, students are able to conclude and use facts.

HOTS Problem: Ball A is thrown vertically up at8 m/s^1. After 0.8 s then from the same point the ball B is also cast vertically up at a speed of 16 m/s^1. The height reached by the ball B when meeting the ball A is ... (gravitational acceleration 10 m/s^2)
(Question 2016 UN number 4)
Discussion of HOTS:

Inorder for B to meet the ball A, the height of ball B is equal to the height of ball A

$\mathrm{h_A} = \mathrm{h_B}$

$v_{0A}t_A - \frac{1}{2}gt_A^2 = v_{0B}t_B - \frac{1}{2}gt_B^2$

$v_{0A}(t + 0{,}8) - \frac{1}{2}g(t + 0{,}8)^2 = v_{0B}t - \frac{1}{2}gt^2$

$v_{0A}t + 0{,}8v_{0A} - \frac{1}{2}g(t^2 + 1{,}6t + 0{,}64) = v_{0B}t - \frac{1}{2}gt^2$

$v_{0A}t + 0{,}8v_{0A} - \frac{1}{2}(10)t^2 - \frac{1}{2}(10)1{,}6t - \frac{1}{2}(10)0{,}64 = v_{0B}t - \frac{1}{2}(10)t^2$

$8t + 6{,}4 - 5t^2 - 8t - 3{,}2 = 16t - 5t^2$

$3{,}2 = 16t$

$t = 0{,}2\ s$

At 0.2 seconds, the height of the ball A is equal to the height of the ball B. So the height achieved by the ball B when meeting with ball A is

$$h = v_{0B}t_B - \frac{1}{2}gt_B^2$$

$h = (16ms^{-1}x\ 0{,}2\ s) - (\frac{1}{2}x10ms^{-2}x0{,}2^2)$

$h = 3{,}2\ m - 0{,}2\ m$

$h = 3{,}0\ m$

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HOTS Problem Analysis: This problem is categorized as HOTS because students are required to be able to conclude the facts by describing two events in the problem as shown in Figure 2 and using it to find solutions to solve problems in the problem. The first event is that the ball A is thrown vertically up with an initial speed of 8 m/s^1. After 0.8 seconds later, from the same point the ball B is also thrown vertically up at a speed of 16 m/s^1. The problem that arises in the problem is to determine the height achieved by B when meeting ball A.

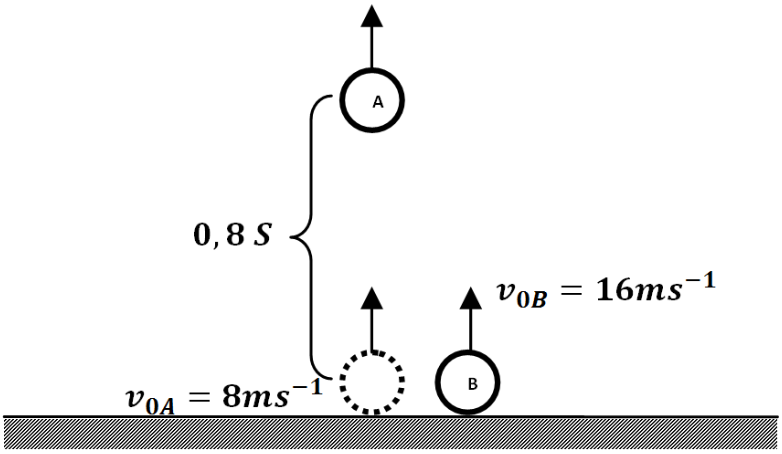
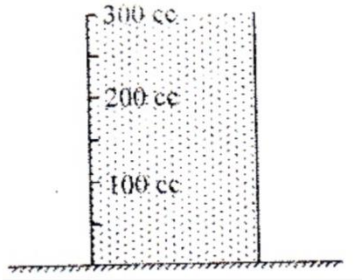


Figure 2. The event of B ball is thrown after 0.8 s

Based on Figure 2, the first fact found in two events is the difference in the time of ball A and ball B when thrown vertically up from the same point. Ball B is thrown 0.8 seconds longer than ball A. The second fact is the amount of height of the ground reached by ball A and ball B so that the two boals meet.

The facts contained in the question are an important key in solving problems in the problem. Using the facts, time will be obtained when ball A and ball B meet after both balls are thrown at 0.2 seconds. The concept used in solving problems is the concept of irregular straight motion (GLBB). So by using the GLBB concept, students are able to determine the height reached by ball B when they meet ball A at 0.2 seconds after the two balls are thrown.

HOTS: Lookat the picture below!



HOTS Question: Consider a bronze vessel with a coefficient of expansion of the image below!$20 \text{ x } 10^{-6}°C^{-1}$Filled with liquid having a coefficient of expansion in volume$540 \text{ x } 10^{-6}°C^{-1}$. The temperature of the vessel with its contents first$20℃$, then heated until the temperature rises to 45 ℃. Spilled fluid volume is ...
(Problem 2016 UN number 18)
Discussion of HOTS:

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The volume of liquid after expanding is

$v_2 = v_1(1 + \gamma < T_2 - T_1 >)$
$v_2 = 300\ cc\ (1 + 540x10^{-6}°\text{C}^{-1} < 45℃ - 20℃ >)$
$v_2 = 300\ cc\ (1 + 13500x10^{-6})$
$v_2 = 300\ cc\ (1 + 0{,}0135)$
$v_2 = 304{,}05\ cc$

The volume coefficient is equal to 3 times the length of the coefficient. So that the volume of the bronze vessel after expanding is

$v_2 = v_1(1 + \gamma < T_2 - T_1 >)$
$v_2 = 300\ cc\ (1 + 60x10^{-6}°\text{C}^{-1} < 45℃ - 20℃ >)$
$v_2 = 300\ cc\ (1 + 1500x10^{-6})$
$v_2 = 300\ cc\ (1 + 0{,}0015)$
$v_2 = 300{,}45\ cc$

Thus, the volume of liquid spilled is the difference in liquid volume with the volume of the bronze vessel that has expanded

$$v_{2cairan} - v_{2bejana} = 304{,}5\ cc - 300{,}45\ cc = 3{,}6\ cc$$

HOTS Problem Analysis: Through the questions presented in the form of pictures and stories, students are required to reason and conclude and use the facts to solve problems in the problem. So this problem is categorized as HOTS. The first fact contained in the problem is the liquid and bronze vessel in the figure, each of which has a coefficient of expansion in volume and a long expansion coefficient. Based on this fact, students are able to reason that not only is the fluid undergoing expansion, but the bronze vessel is also experiencing expansion after being heated. So there are two events in the problem, namely the expansion of liquid and bronze vessels at one time. The problem that arises in the problem is to determine the volume of liquid spilled after being heated.

The second fact is the difference in the volume of liquid and bronze vessels after experiencing expansion is a large volume of liquid spilled. In finding the volume of the bronze vessel after expansion, the length of the expansion coefficient of the bronze in the problem is related to the coefficient of expansion of the volume. The coefficient of expansion in volume is equal to 3 times the coefficient of length.

After obtaining the final bronze volume, the problem in the problem can be solved by finding the difference in volume of the liquid and bronze vessel after being heated. Through this HOTS question, students do not just repeat the facts by using the formula for expanding the volume of liquid that has been memorized. But students must also be able to deduce the facts about the effect of expansion of bronze vessels on fluid expansion and use the facts obtained to determine the large volume of liquid spilled.

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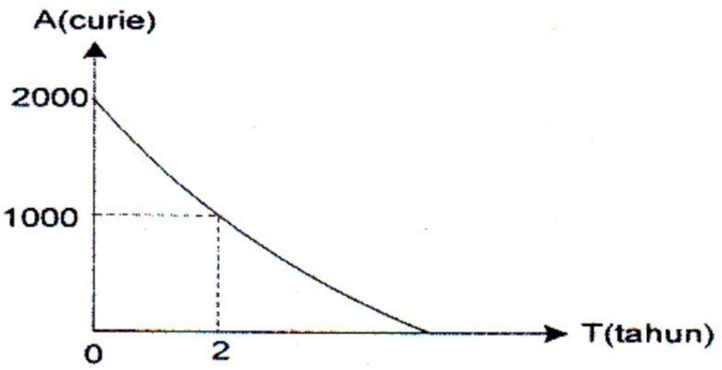
HOTS Problem: Pay attention to the graph of decay of the following radioactive material!



Substance activity remained 125 curies after time ...
(Problem 2016 UN number 40)

Discussion of HOTS:

- Initial substance activity is 2000 curies
- half time is 2 years
- decay order$\lambda = \frac{ln2}{T\frac{1}{2}} = \frac{ln2}{2tahun} = \frac{0,34657}{tahun}$
- Substance activity when staying 125 curies

$R = R_0 e^{-\lambda t}$

$125 = 2000e^{-\frac{0,34657}{tahun}t}$

$\frac{125}{2000} = e^{\frac{-0,34657}{tahun}t}$

$0,00625 = e^{\frac{-0,34657}{tahun}t}$

$ln0,00625 = \frac{-0,34657}{tahun}t$

$-2,772589 = \frac{-0,34657}{tahun}t$

$t = 8\ tahun$

HOTS Problem Analysis: The problem is presented in graphical form of the decay activity of a radioactive material over time. The facts contained in the graph are the initial decay activity and the time interval needed for the radiation activity to decrease by half the original activity. The initial substance activity was 2000 curies and the half-time of the substance was 2 years. Students can use the facts that have been obtained to determine the time needed for the activity of the substance to stay 125 curies. This problem is categorized as HOTS, because in solving problems students must be able to deduce facts through graphs and use them in finding solutions. So that students are able to think for a higher level than repeating the facts.

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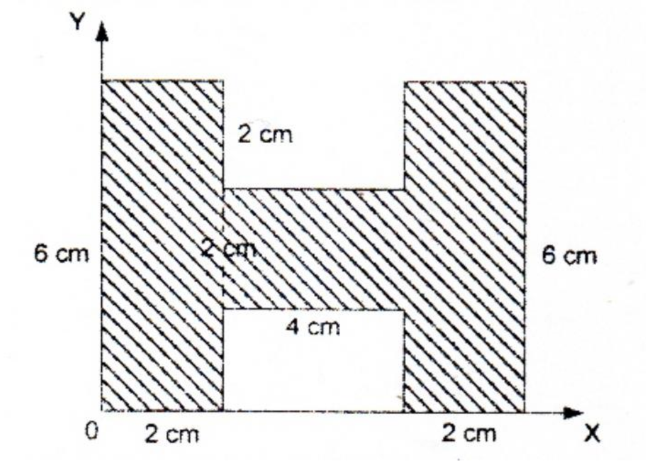
HOTS Problem: Pay attention to the following picture!



The position of the point-bearing coordinates of the letter H is .... (Problem UN 2016 number 10)

Discussion of HOTS:
To find the location of the coordinates of the center of gravity in the form of the letter H, determine the symmetry of the folding plane by dividing the two fields horizontally and vertically.

- Vertically

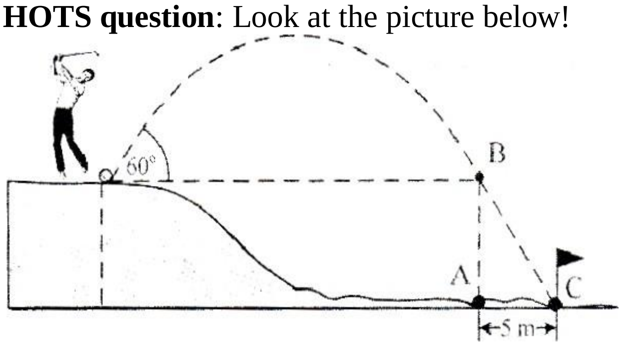
$$\frac{\text{Tinggi bidang}}{2} = \frac{6\ cm}{2} = 3\ cm$$

- Horizontally

$$\frac{\text{Lebar bidang}}{2} = \frac{8\ cm}{2} = 4\ cm$$

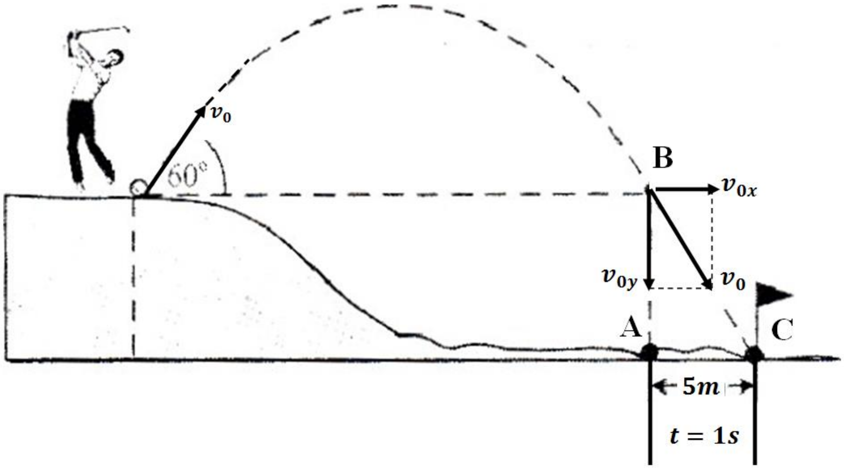
So that the location of the coordinate center of gravity is (4.3)
HOTS Problem Analysis: The facts contained in the problem are the fields in the image have fold symmetry vertically and horizontally. This problem is categorized as HOTS, because students must be able to deduce the facts contained in the picture and use them in solving problems in the problem.

HOTS question: Look at the picture below!



In a golf game, a ball with a mass of 0.2 kg (g = 10 m/s^2) will be inserted into hole C as shown in the picture. The batter touches the ball within 001 seconds and the B-C path is taken by the ball within 1 second. The style that a golfer needs to hit the ball to get right into the hole C is ... (Problem 2016 UN number 6)

Discussion of HOTS :



Gambar 3. Arah kecepatan mula-mula bola golf

The speed on the x axis from A to C is

$v_x = \frac{s}{t}$

$v_x = \frac{5m}{1s} = 5ms^{-1}$

So that the initial speed of the ball is

$v_x = v_0 \, cos60°$

$v_t = \frac{v_x}{cos60°}$

$v_t = \frac{5ms^{-1}}{0,5}$

$v_t = 10 \, ms^{-1}$

The final velocity of the ball to fit into the hole C is 10 m/s^1. So the momentum change that happened is

$I = \Delta p$

$F.\Delta t = m(v_t - v_0)$

$F(0,01s) = \ 0,2 \, kg(10 - 0)$

$F(0,01s) = \ 0,2 \, kg(10 \, m.s^{-1})$

$F = \frac{2 \, kgm.s^{-1}}{0,01 \, s}$

$F = \ 200N$

HOTS Problem Analysis: This problem is categorized as HOTS because it is presented in the form of pictures and stories by using examples in everyday life, so that students do not only memorize facts. But students are able to reason by finding and summarizing facts as in Figure 3 and connecting a concept and other concepts.

The fact contained in Figure 3 is the direction of the speed of the golf ball first to form an angle of 60 ° to the ground. This is because the speed of the golf ball is in the direction of the force given by the player to the ball. Based on the facts contained in the problem, students can conclude that the concept that occurs in the picture is parabolic motion. In solving problems in the problem, students must understand that parabolic motion applies the GLB concept on the x-axis and GLBB on the y-axis. So that the initial speed can be determined by applying the GLB concept from point B to point C which is 5 meters away and taken by the ball for 1 second.

The second fact obtained through the story contained in the problem is that the player touches the ball within 0.01 seconds, so the concept of impulse and momentum applies. Using these facts, students are able to relate the concept of irregular straight motion to the concept of impulse and momentum in determining the force needed by the golfer to hit the ball so that it enters the hole.

HOTS Problem: A ball with a mass of 200 grams falls freely without initial speed from a height of 1.8 m above the floor and the ball bounces back at a speed of 2 m/s^1 (acceleration of gravity = 10 m/s^2). Large impulses on the ball are ...

(Problem 2016 UN number 17)

Discussion of HOTS:

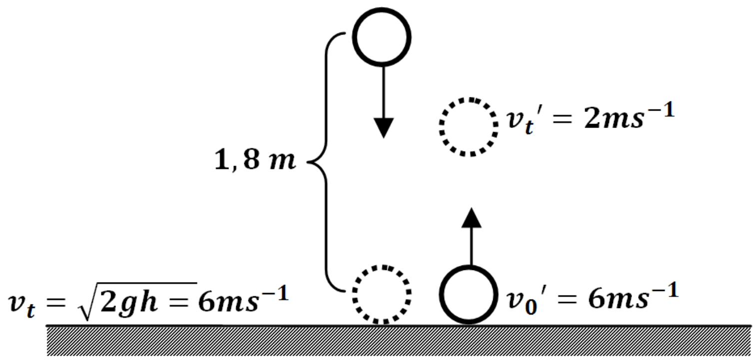


Figure 4. The free-falling ball event

The final speed of the ball falls freely into the initial speed of the ball when it bounces back. So that the ball impulse is large

$I = \Delta p$

$I = m(v_t{}' - v_0{}')$

$I = 0{,}2\ kg\ \left(2\frac{m}{s} - 6\frac{m}{s}\right)$

$I = 0{,}2x(-4)\ kg.\frac{m}{s}$

$I = -0{,}8Ns$ (the minus sign just shows the direction)

HOTS Problem Analysis: This problem is categorized as HOTS because students are required to be able to deduce facts by describing events that occur as in Figure 4. The facts contained in the problem are mass-mass events that fall free and bounce back at a certain speed. Based on the facts obtained it can be concluded that there is a concept of free fall motion and the concept of impulse and momentum in solving problems in the problem.

Based on Figure 4, it can be seen that the final velocity when the ball hits the ground is 6 m/s^1 obtained using the concept of free fall motion. When the ball bounces back at 2 m/s^1 the concept of impulse and momentum applies. So that the final speed when touching the ground is used as the initial speed to determine the magnitude of the impulse on the ball. This problem is

categorized as HOTS because students must be able to connect the concept of free fall motion with the concept of impulse and momentum in solving problems in the problem.
Based on the results of the analysis, the questions categorized as HOTS amounted to 6 questions, so it has a percentage of 15%. This is in accordance with the percentage of HOTS in the National Examination questions based on the research of Ramadhan & Wasis (2013: 22) and Syahida & Irawan (2015: 77) which states that the percentage of HOTS questions in the National Examination both at the high school and junior high school ranges from 7.5% - 15 %.

HOTS Analysis Data for Students in the 2016 Physics UN

The research data was taken in November 2015 - January 2016. The research was carried out by carrying out a National Physics Try Out Test in MAN 2 Model Pekanbaru on November 18, 2016. Consisting of 5 classes of students in class XII with 129 students. The questions are tested in the form of 3 question packages, each of which consists of 40 Physics questions. The UN Physics questions categorized as HOTS are questions number 4, 6, 10, 17, 18, and 40 with the HOTS indicator concluding and using facts and concluding facts and connecting concepts. The following is the number and percentage of students who answered HOTS questions correctly.

Table 2. Number of Students Answering HOTS Questions Correctly.

No	Indicator about HOTS	Number about HOTS UN	Number of students who answered correctly	Percentage of Students Who Answer Right
1.	Summing up and using facts	4	41	31,78 %
		10	77	59,69%
		18	58	44,96 %
		40	52	40,31 %
2.	Summing up facts and connecting concepts	6	91	70,54 %
		17	37	28,68 %

Based on Table 2, HOTS questions that were answered correctly with the least number of students were problem number 17 which was presented in the form of stories using examples in daily life. Problems contained in the problem require students' reasoning skills in finding facts and connecting the concept of GLBB with the concepts of impulse and momentum. While the questions answered correctly with the highest number of students were number 6 which was presented in the form of pictures and stories using examples in everyday life. Problems contained in the problem require students' reasoning ability to conclude and connect a concept and fact of GLBB with the concepts of impulse and momentum. The following percentage of

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students who answered HOTS questions correctly were presented in graphical form in Figure 4.

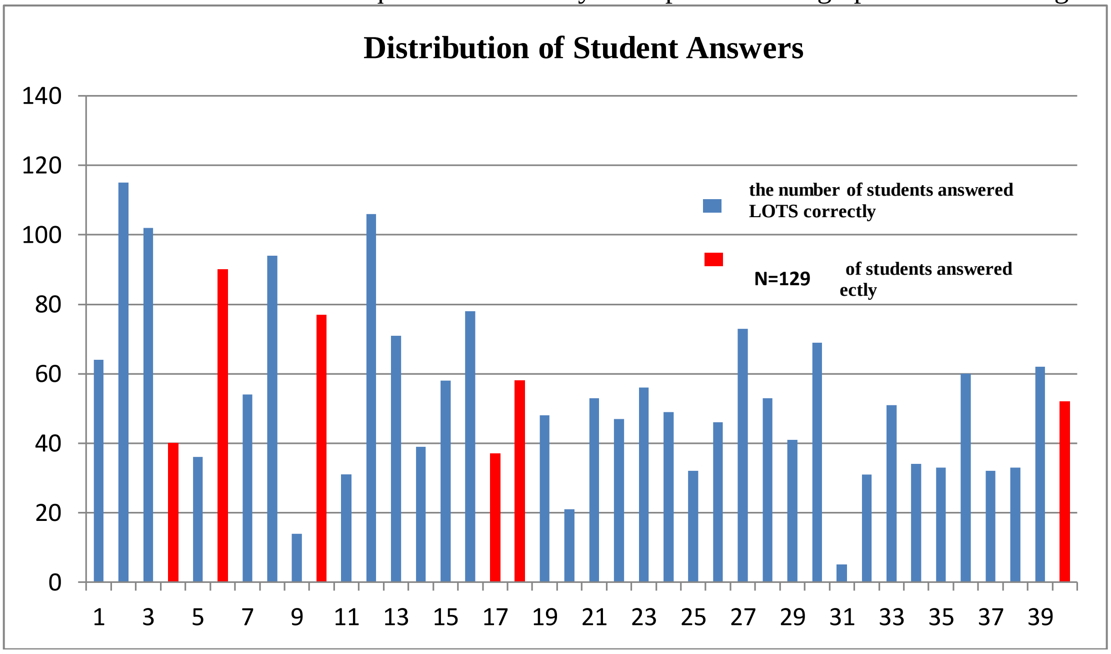

Figure 5. Distribution charts of student answers

Based on the graph in Figure 5, the highest level of difficulty based on the number of students who answered correctly was problem number 31. This was due to the lack of students' ability to understand the concepts contained in the questions presented in the form of pictures and stories. The concept that must be understood by students is the direction of electrical force experienced by the object at point A due to the charge at point B and C. Students must understand that the force of electricity is a vector quantity. So that students can determine the resultant electrical force experienced by the charge at point A. If students understand this concept, students will easily solve the problems found in the problem, namely determining the electrical force experienced by the charge at point A. However, this problem is categorized as LOTS because not in accordance with LOTS criteria and indicators according to Thomas & Thorne (2010). Difficulties of students of MAN 2 Model in answering this problem are due to the lack of habit of students in working on this problem. While the problem with the lowest difficulty level based on the graph is the number 2 problem categorized as LOTS.

Based on the graph in Figure 5, only 4 questions with LOTS category were able to be answered by students with more numbers than questions number 6 categorized as HOTS. This is due to the lack of students in remembering the formulas used in solving other LOTS problems. Another factor was that students had not yet studied the physics material of XII even semester when the research was carried out. The large number of students who are able to answer questions number 6, shows the ability of the Man 2 Model Pekanbaru students to master parabolic motion material and impulses and momentum. So that students are able to reason in working on questions presented with two different concepts.

The average ability of students in answering HOTS questions is still categorized as moderate. According to Thomas & Thorne, HOTS can be learned and taught to students. Problem-based learning methods can improve students' high-level thinking skills. This is supported by the research of Widodo & Kadarwati (2013: 168) that problem-based learning can increase students' courage in facing difficult problems. The selection of problem-based learning strategies is intended so that students want to learn more actively with the challenges of solving problems that require higher level thinking. This is reinforced by the results of Ersoy & Başer's (2013: 3496) research which states that before and after the problem-based learning process (PBL), there is a significant difference in creativity in students which is one of the higher-order thinking skills. Through PBL, students are able to find ideas that help students in identifying and solving problems. So that problem-based learning is very suitable to be applied in improving students' high-level thinking skills.

4. Conclusion

The results of the study show that: (1) based on the percentage of questions that require high-level thinking skills of students, the Physics UN problem is able to measure students' high-level thinking skills; (2) Higher Order Thinking Skills of MAN 2 Pekanbaru Model students in completing national physics exam questions are categorized as not good.

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