Phys. Comm. 4 (1) 2020 : 24 - 32

Physics Communication

http://journal.unnes.ac.id/nju/index.php/pc

Conceptual Problem Solving and Student's Empirical Inductive Reasoning in Elasticity Subject

Restina Muji Mulyati✉, Sunyoto Eko Nugroho, Sulhadi

Postgraduate Universitas Negeri Semarang, Semarang, Indonesia

Article Info

Article history:
Received 17 December 2019
Approved 21 February 2020
Published 28 February 2020

Keywords:
elasticity, physics learning, conceptual problem solving, empirical inductive reasoning

Abstract

Conceptual problem solving skills are one of the factors for student success in learning physics. Problem solving skills have a close relationship with reasoning skills. This study aims to analyze conceptual problem solving and student's empirical inductive reasoning in learning physics in elasticity subject. This study used a quasi-experimental method with a one-shot case study research design. The research data were obtained from written tests. For conceptual problem solving skills, the average score percentage for principle aspects was 50.79%, justification aspects 3.17%, and plan aspects 38.49%. The results showed that the aspects of student justification in the elasticity subject were still low. Students have not been able to provide a complete explanation of why a principle or law of physics applies to a problem. For empirical inductive reasoning skills, the percentage score for the class inclusion pattern average was 31%, the conservation pattern was 10%, and the serial ordering pattern was 38%. Students have not been able to apply conservation thinking to an object, meaning that students do not understand that if nothing is added or removed from an object, then the properties or characteristics of the object will remain the same even though their appearance is different. The research results are expected to provide benefits, namely: (1) for students, as motivation to improve learning performance so that good learning outcomes are achieved, and (2) for teachers, as a basis for applying appropriate learning methods to develop student's conceptual problem solving and empirical inductive reasoning skills.

✉Correspondence:
Postgraduate Universitas Negeri Semarang
Jalan Kelud Utara III No. 37, Kota Semarang, Indonesia 50237
e-mail: restinaphysics@yahoo.com

p-ISS N 2528-5971
e-ISSN 2528-598X

INTRODUCTION

Solving problems is one of the daily activities of students in learning at school. This problem solving involves a complex thought process. Students are required to have good problem solving skills in the face of the rapidly developing scientific and technological age. Facts in the field show that most students have difficulty solving physics problems. Snetinova & Koupilova (2012), Syukri et al. (2012), and Nurhayati et al. (2016) found that the difficulty of solving physics problems is supported by the problem solving process without recognizing or understanding the physics concepts associated with the problem. Understanding the concepts involved in this problem really helps students in determining the next steps to solve the problem appropriately. According to Docktor et al. (2015), conceptual problem solving consists of three parts, namely: (1) principle (principles or concepts that apply to problems), (2) justification (explanation of why the principle or concept is in accordance with the problem), and plan (problem solving step by step plan).

Another thinking skill that is closely related to problem solving skills is reasoning skills. Reasoning as a combined form of basic, critical, and creative thinking is needed by students in learning physics. One of the patterns of scientific reasoning according to Lawson (1995) is the empirical inductive pattern, which is a person's thinking pattern in describing objects, events, and situations in their environment accurately. The empirical inductive pattern consists of: (1) class inclusion (understanding simple classifications and generalizations), (2) conservation (applying conservation thinking to visible objects and properties), and (3) serial ordering (arranging a set of objects or data serially). With this pattern of thinking, students can understand simple physics concepts that refer directly to objects that can be observed and can be explained in terms of simple relationships. In fact, it was found that student's scientific reasoning in physics learning was still low (Hermawanto et al., 2013; Shofiyah et al., 2013). Daryanti et al. (2015) also found that all aspects of student's scientific reasoning were still below 50%.

Based on the explanation above, it is necessary to improve student's conceptual problem solving and empirical inductive reasoning skills. Before making these improvement efforts, it is necessary to study first how conceptual problem solving skills and empirical inductive reasoning of students in Semarang city in physics learning, especially in elasticity subject. The reason for the elasticity subject chosen in this study is because it is very familiar with daily life and can be visualized and various problems regarding elasticity can be arranged in accordance with conceptual problem solving and empirical inductive reasoning pattern to be measured.

A study of student's conceptual problem solving skills and empirical inductive reasoning needs to be done because it refers to the observations of Kharida et al. (2009) which shows that the average score of SMA Sultan Agung 1 Semarang students on the elasticity subject is 64.5, which is classified as low. In addition, in several other areas outside the city of Semarang, there were various misconceptions experienced by students on the subject of elasticity. In SMA N 4 Jember, it was found that 26% of students had misconceptions and 18% of students had no understanding of the concept of elasticity (Nisa et al., 2019), while in SMA N 1 Indralaya it was found that 51.05% of students had misconceptions on elasticity and Hooke's law subject and 8.38% of students do not understand the concept (Hidayati et al., 2016). Some of the misconceptions experienced by students on the elasticity subject include: (1) energy can appear and disappear, (2) the elastic energy that a spring has when it is compressed is smaller than the elastic energy of the spring before it is compressed, (3) elastic objects have no elastic limits (4) the modulus of elasticity is a measure of the ability of a material to return to its original shape after being subjected to pressure, and (5) objects that have a greater bending power have a larger modulus of elasticity. Several previous studies have become the basis for conducting this research in order to assess the conceptual problem solving skills and empirical inductive reasoning of students in the Semarang city on the elasticity subject.

METHOD

This study used a quasi-experimental method with a one-shot case study design. The subjects of this study were twenty-one students of class XI IPA SMA Walisongo Semarang for the 2019/2020 academic year. Data collection was carried out through written tests to analyze student's conceptual problem solving and empirical inductive reasoning. Analysis of problem solving in terms of three parts according to Docktor et al. (2015), namely: principle, justification, and plan. For empirical inductive reasoning analysis is carried out based on three patterns, namely: class inclusion, conservation, and serial ordering (Lawson, 1995).

RESULTS AND DISCUSSION

Student's Conceptual Problem Solving

Data on student's conceptual problem solving skills were obtained through written tests. This test consists of 3 items in the description of the elasticity subject. Item 1 about Hooke's law and the principle of the arrangement of series and parallel springs. Item 2 about the change of gravitational potential energy into spring potential energy and about Newton's second law and Hooke's law. Item 3 about Newton's third law and Hooke's law. Student's answers were analyzed based on three aspects, namely principle, justification, and plan. The plan aspect consists of visualizing the problem, writing the quantity and unit symbols, mathematical equations, and calculating answers. The percentage score for each aspect of conceptual problem solving for each item is shown in Figure 1.

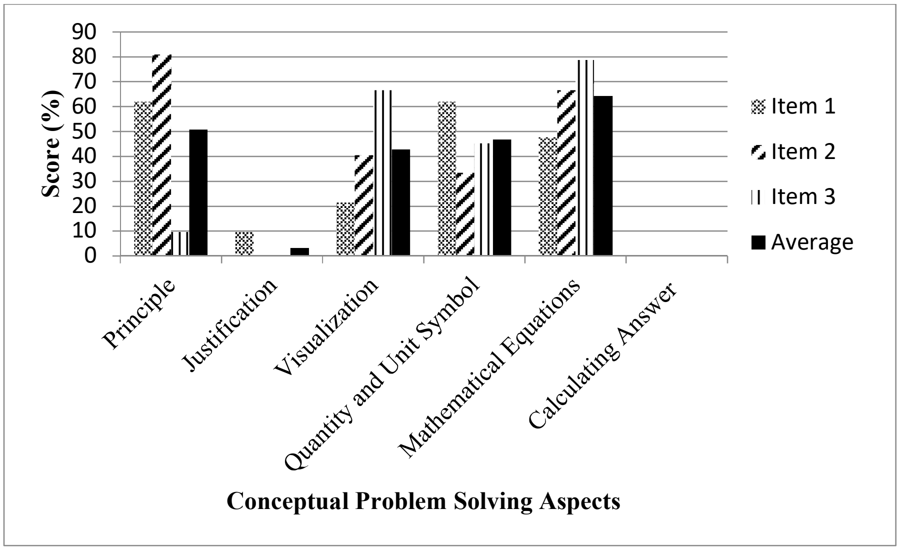
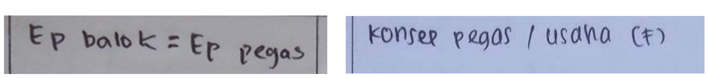


Figure 1. Percentage of Conceptual Problem Solving Aspect Scores for Each Problem Item

In Figure 1, it can be seen that the principle aspect with the achievement in item 2 is 81% and the lowest is 10%. Aspect Justification obtained a score only on item 1 of 10%. For the planning aspect, the average score is obtained on mathematical equations, then the quantity and unit symbols are obtained, visualization of the problem, and the lowest average is obtained in the calculation of answers. Overall, students obtained the highest average score in determining the appropriate mathematical equation, while the lowest average score was obtained in the justification aspect. When averaged for each aspect, the percentage score for principle aspect is 50.79%, justification aspect is 3.17%, and plan aspect is 38.49%.The following is an explanation of each aspect of student conceptual problem solving:

1. Principle Aspect

In the principle aspect, students are asked to write down principles or concepts that apply or can be applied to problems. For example in item 2 (the item with the highest principle aspect score), a picture of a block falling from a certain height from the floor is presented. The block falls right on the upper end of a spring with a certain spring constant. The spring is then compressed by a few centimeters. Students are asked to determine the mass of the blocks. The principle for solving problem 2 is the amount of gravitational potential energy of the block changes entirely to potential energy of the spring. In Figure 2 (a) it appears that the students were correct in determining the principles for solving item 2 (potential energy of block = potential energy of spring).



(a) (b)

Figure 2. Student's Principle Aspects: (a) Item 2 and (b) Item 3.

For comparison, question item 3 (the item with the lowest principle aspect) shown in Figure 3.

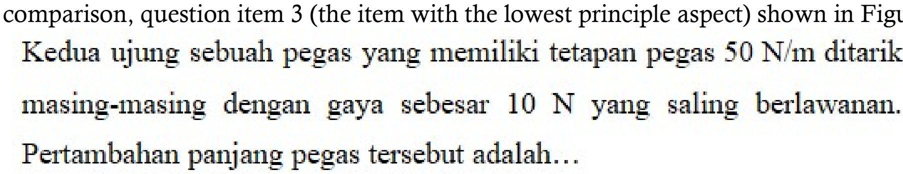

Kedua ujung sebuah pegas yang memiliki tetapan pegas 50 N/m ditarik masing-masing dengan gaya sebesar 10 N yang saling berlawanan. Pertambahan panjang pegas tersebut adalah…

Figure 3. Item 3 of The Conceptual Problem Solving Test.

Item 3 explains about a spring with a certain spring constant whose both ends are pulled by an equal force opposing each other. Students are asked to determine the increase in the length of the spring. The law involved in solving item 3 is Hooke's law with action-reaction force or you can use Hooke's law where the springs are considered to be two identical springs arranged in series. In Figure 2 (b), it appears that the students mentioned the work concept for solving item 3, but the business concept was not appropriate for solving item 3.

Students who have not been able to master the concept will have difficulty solving problems and have an impact on cognitive learning outcomes (Supiandi & Julung, 2014). Lin & Singh (2013) also stated that identifying the relevant physics principles contained in the problem is an important component in solving physics problems. So, a good understanding of the concepts and principles of physics is needed in order to get the right problem solution. The development of student's understanding of concepts and principles can be done by asking students to qualitatively (conceptually) analyze the problems presented. In other words, students are not only fixated on which formula is appropriate to solve the problem.

2. Justification Aspect

In the justification aspect, students are asked to write an explanation of why the concept, law, or principle they choose is in accordance with the problem. For example, Figure 4 shows question item 1.

Sebuah pegas panjangnya 50 cm. Jika diberikan gaya 200 N, pegas bertambah panjang 10 cm. Pegas tersebut dipotong menjadi dua bagian sama panjang, kemudian keduanya disusun paralel. Tentukan kontanta pegas gabungan tersebut!

Figure 4. Item 1 of The Conceptual Problem Solving Test.

In item 1, it was explained about a spring that is applied a force, so that the spring increases in length. Next, the spring is cut into two equal long and the two are arranged in parallel. Students are asked to determine the combined spring constant. The laws and principles that correspond to this problem are Hooke's law ($F = k\,\Delta x$) and the principle of the series-parallel spring arrangement. In this study, students wrote "Hooke's law", and "series and parallel combined spring constants" on the principle aspect. This shows that students do not understand the physics principles involved in item 1 (the principle of the series-parallel spring arrangement). Even so, students already know that Hooke's law applies to the problem.

Explanation why Hooke's law and the principle of series-parallel spring arrangement can be applied to item 1, namely Hooke's law is used to determine the initial spring constant (before the spring is cut). Next, to find the spring constant after the spring is cut in half, we reverse the analogy. If the two pieces of the spring are put together again in series into one whole spring, then the combined spring constant will be the same as the original spring constant $\left(\frac{1}{k_{piece}} + \frac{1}{k_{piece}} = \frac{1}{k_{initial}}\right)$. The two springs are then arranged in parallel, so that the combined constant value of the springs can be found using the principle of parallel spring arrangement. Figure 5 presents student's answers to the justification aspects of item 1.

karena yg dicari konstanta pegas

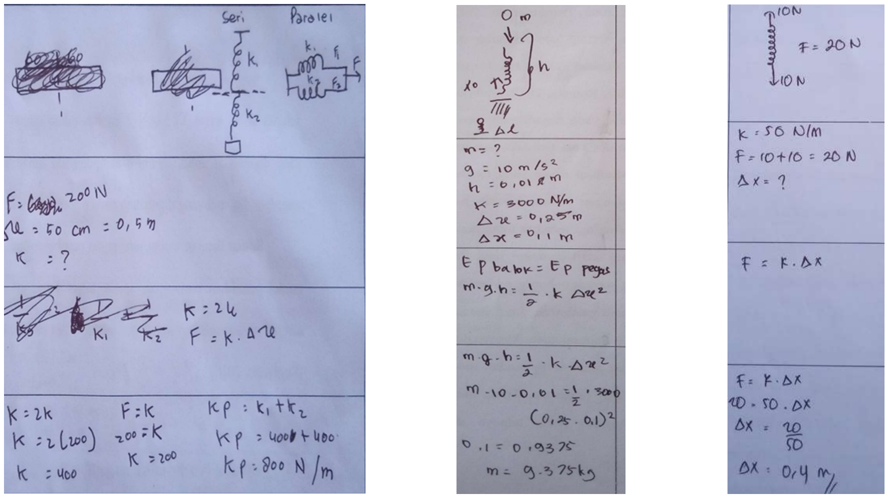
karena dipotong sama panjang & yg dicari konstanta pegas

Figure 5. Student's Justification Aspects in Item 1.

Figure 5 shows that students have not giving a thorough justification. Students know that in solving these problems there are stages to find the spring constant, but they have not fully explained what principles are used when a spring is cut into two parts and then combined in parallel. This can be caused by student's weaknesses in analyzing problems, inaccurate thinking, inaccurate reading, or lack of persistence (Whimbey & Lochhead quoted by Setyono et al., 2016). The student's ability in this problem affects the determination of the next steps, such as determining the right mathematical equation.

3. Plan Aspect

In plan aspect, students are asked to visualize the problems presented, write down symbols of quantity and unit, write down appropriate mathematical equations, and calculate numerical answers. The student's plan aspects for each item are shown in Figure 6.



(a) (b) (c)

Figure 6. Student's Plan Aspects: (a) Item 1, (b) Item 2, and (c) Item 3.

In Figure 6 (a) it can be seen that students can describe a spring that is cut into two equal parts (in series) then the two parts of the spring are joined in parallel. Students can also visualize an object that is dropped onto a spring (Figure 6(b)), it's just that the limits of the magnitudes l_0 (the initial length of the spring) and h (the height of the object from the top of the spring) are not right. Figure 6(c) shows that the student is describing a spring with equal force on both sides. For writing the quantity and unit symbols, students have written the quantity and unit symbols correctly. In determining mathematical equations, students have written mathematical equations of gravitational potential energy, spring potential energy, Hooke's law, and the combined constant of parallel springs correctly, it's just that they are still wrong in determining the constant of a spring that comes from a spring that is cut into two equal parts. For calculating numerical answers, students get the lowest score. The reasons include students who are not careful in calculating, have difficulty performing calculation operations, and teachers rarely provide various questions (Charli et al., 2018). In this study, even though students were able to clearly visualize the problem, the solutions obtained were not always correct. This can happen because problem solving also depends on the correctness of the concepts used and evaluation of problem solutions (Sujarwanto et al., 2014).

From the explanation above, it can be concluded that in order to obtain good problem solving results, it is necessary to have harmony between the aspects of principle, justification, and plan. This is confirmed by the research results of Ali et al. (2014) stated that students who are more successful in problem solving are quick to understand the meaning of questions, determine goals clearly, draw diagrams, and analyze qualitatively before and during the problem solving process.

Student's Empirical Inductive Reasoning

Data on student's empirical inductive reasoning skills were obtained through written tests. This test consists of 3 items in the description of the elasticity subject which are adjusted to three empirical inductive reasoning patterns. Figure 7 shows the percentage average score of each empirical inductive reasoning pattern. Item 1 measures the class inclusion pattern, item 2 measures the conservation pattern, and item 3 measures the pattern of serial ordering.

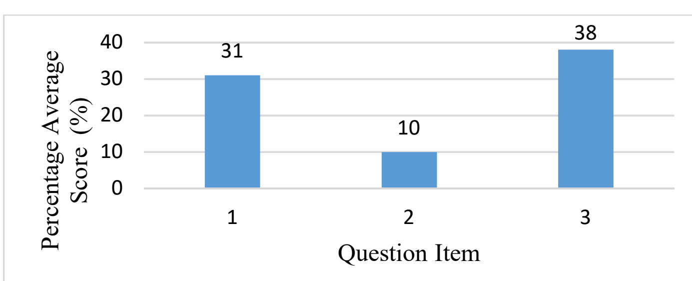


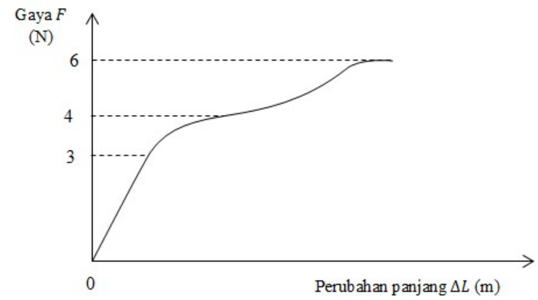
Figure 7. Percentage Average Score of Each Empirical Inductive Reasoning Pattern.

The following is an explanation of each student's empirical inductive reasoning pattern:

1. Class inclusion

Item 1 of the empirical inductive reasoning test is shown in Figure 8.

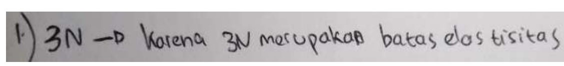
1. Perhatikan gambar di bawah ini.



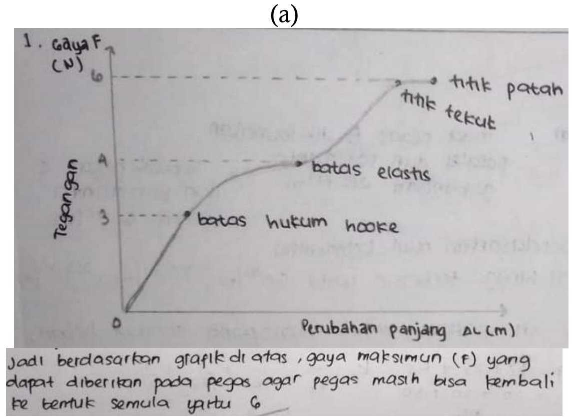
Berdasarkan gambar di atas, berapa gaya maksimum yang dapat diberikan pada pegas agar pegas masih bisa kembali ke bentuk semula?
Jawaban:
Penjelasan:

Figure 8. Item 1 of The Empirical Inductive Reasoning Test.

In Figure 8, is shown a graph of the relationship between spring force and change in spring length is presented. Students are asked to determine the maximum force that can be applied to the spring so that the spring can still return to its original shape. The empirical inductive reasoning skills that students must have to be able to answer item 1 are classifying linearity limits, elasticity limits, and breaking points on the graph of the relationship between spring force and changes in spring length and understanding and applying the elasticity limit description. Student's answers and reasons for item 1 (class inclusion) are shown in Figure 9.



(a)



(b)

Figure 9. Student's Class Inclusion Skills.

Figure 9(a) shows that students understand that the spring can still return to its original state if the elasticity limit is not exceeded, but the student has not been able to classify the linearity and elasticity limits on the graph of the relationship between the spring force and the change in spring length. Figure 9(b) shows that students have been able to classify linearity limits (Hooke's law limits), elasticity limits, and breaking points, but these students do not understand the maximum force that can be exerted so that the spring can still return to its original state, is not exceeding its elasticity limit.

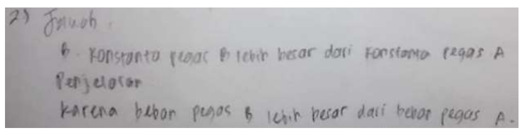
2. Conservation

Figure 10 shows item 2 of the empirical inductive reasoning test.

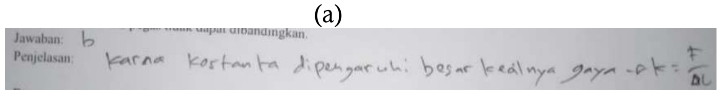
2. Dua buah pegas A dan B dengan ukuran dan bahan yang sama digantungkan pada sebuah statif. Pegas A diberi beban 10 N dan pegas B diberi beban 20 N. Mana pernyataan berikut ini yang benar?
   a. Konstanta pegas A lebih besar dari konstanta pegas B.
   b. Konstanta pegas B lebih besar dari konstanta pegas A.
   c. Konstanta kedua pegas sama besar.
   d. Konstanta kedua pegas tidak dapat dibandingkan.
   Jawaban:
   Penjelasan:

Figure 10. Item 2 of The Empirical Inductive Reasoning Test.

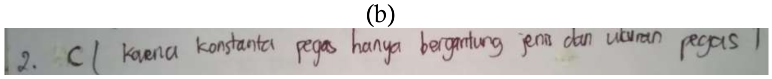
Item 2 in Figure 10 describes two springs which have the same size and material, but are given different weights. Students are asked to compare the constants of the two springs. The empirical inductive reasoning skills that students must have in order to be able to answer item 2 are applying conservation thinking, which is understanding that the spring constant does not change as long as the size and spring material used are the same. Figure 11 shows the student's answers and reasons for item 2.


2) Jawab :
b. Konstanta pegas B lebih besar dari konstanta pegas A
Penjelasan
karena beban pegas B lebih besar dari beban pegas A.

(a)


Jawaban: b
Penjelasan: karna kostanta dipengaruhi besar kecilnya gaya → $k = \frac{F}{\Delta L}$

(b)


2. C / karena konstanta pegas hanya bergantung jenis dan ukuran pegas

(c)

Figure 11. Student's Conservation Skills.

Figures 11(a) and 11(b) show that students consider the size of the spring constant to be influenced by the size of the load hanging on the spring. Whereas the size of the spring constant is influenced by the characteristics of the spring itself, namely the size and material of the spring. The student in Figure 11(b) also explains that the size of the spring constant is directly proportional to the magnitude of the force, by applying Hooke's law. Whereas the meaning of Hooke's law is the magnitude of the change in the length of the spring is directly proportional to the magnitude of the force exerted on the spring. For Figure 11(c), students provide the correct answers and reasons, so it can be said that the student is able to apply conservation thinking. Students understand the concept that the spring constant only depends on the type and size of the spring, so that if there are two springs that have the same size and material, then the spring constant value of the two springs is the same.

3. Serial Ordering

Item 3 of the empirical inductive reasoning test is shown in Figure 12.

3. Dua pegas A dihubungkan paralel mempunyai konstanta gabungan 100 N/m. Tiga pegas B dihubungkan paralel mempunyai konstanta gabungan 210 N/m. Sebuah pegas C mempunyai konstanta pegas 60 N/m. Urutkan pegas berdasarkan nilai konstanta pegasnya dari yang terkecil hingga yang terbesar!
   Jawaban:
   Penjelasan:

Figure 12. Item 3 of The Empirical Inductive Reasoning Test.

Item 3 in Figure 12 describes several springs. Students are asked to sort the springs based on the value of the spring constant. The empirical inductive reasoning skills that students must have to answer item 3, is applying the formula to determine the combined constant of a parallel spring arrangement. The student's answers and reasons for item 3 are shown in Figure 13. Figure 13 shows that students understand the meaning of the questions well as evidenced by visualizing the problem.

Students are also able to determine the constant size of a spring from several springs arranged in parallel, by applying the formula for the combined spring constants for a parallel arrangement.

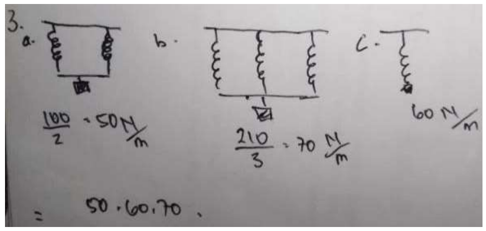


Figure 13. Student's Serial Ordering Skills.

The results of this study illustrate that the best empirical inductive reasoning skills achieved by students are in the aspect of serial ordering and the lowest achievement is in the aspect of conservation reasoning. The student's low scientific reasoning skills can be caused by several things. First, students are accustomed to answering questions based on prior knowledge, not by relying on information contained in the problem (Wooley et al., 2018). This will be a problem if the knowledge understood by students is wrong and students do not analyze the problem. Students are not used to analyzing problems because teachers tend to develop learning by providing as much subject as possible in the hope that students are able to master and apply this knowledge (Gotwals and Songer, 2009). Students who are facilitated with learning methods and media that do not support students in analyzing problems, evaluating information, thinking critically, and creatively will not be formed good reasoning skills in these students. Second, students analyzing a quantitative problem does not involve qualitative analysis aka determining a solution to the problem using only a memorized formula. Singh (2016) suggests that consistently using qualitative problem analysis and planning solutions based on relevant physics principles can help students develop reasoning skills.

Therefore, student's reasoning skills need attention and be trained by the teacher in the learning process. Novia & Riandi (2017) explain that the development of scientific reasoning requires a lot of practice and patience because scientific thinking is a complete collection of cognitive skills. So, good scientific reasoning skills are not automatically formed in a short time and of course an appropriate learning method is needed to train student's scientific reasoning skills. In addition, Damawati and Juanda (2016) also suggest that reasoning is related to all thought processes that shaping learning, such as problem solving and decision making. With good scientific reasoning skills, students can solve problems well and can make correct decisions.

The implication of the results of this study for the field of Physics Education is that it provides information that there are still many students who experience misconceptions on elasticity subject. Teachers are expected to be able to design and apply attractive learning models or methods to teach the concepts of elasticity, so that students understand the concepts of elasticity and can solve physics problems in elasticity subject properly. In addition, in learning physics, teachers are also expected to not only provide as much physics subject as possible, but facilitate students to be able to develop physics problem solving and reasoning skills.

CONCLUSIONS AND SUGGESTIONS

Based on the research results, it can be concluded that the student's conceptual problem solving skills in the elasticity subject still need to be improved, especially in the principle and justification aspects. Students need to be trained to analyze problems, not only quantitatively, but also qualitatively, so that student's understanding of concepts increases and students can explain why these concepts apply in solving a problem. On the other hand, student's empirical inductive reasoning skills, especially conservation patterns also need to be developed. This is because good scientific reasoning skills will help students solve problems well. Therefore, suggestions for further research are to design and implement efforts (models, methods, or learning techniques) to improve student's conceptual problem-solving skills and scientific reasoning.

ACKNOWLEDGEMENT

The first thanks are addressed to the Principal of SMA Walisongo Semarang, who has allowed to carry out research in class XI IPA SMA Walisongo Semarang for the 2019/2020 school year. Further thanks are addressed to Dr. Sunyoto Eko Nugroho, M.Si and Dr. Sulhadi, M.Si, who has guided this research well.

REFERENCES

Ali, M., Ibrahim, N. H., Surif, A. J., & Saim, N. 2014. Physics Problem Solving Strategies and Metacognitive Skills. Force and Motion Topics. *IEEE 6th International Conference on Engineering Education*: 133-138.

Charli, L., Amin, A., & Agustina, D. 2018. Kesulitan Siswa dalam Menyelesaikan Soal Fisika pada Materi Suhu dan Kalor di Kelas X SMA Ar-Risalah Lubuklinggau Tahun Pelajaran 2016/2017. *Journal of Education and Instruction*, 1(1): 42-50.

Damawati, N. A. C. & Juanda, E. A. 2016. Pengaruh Inquiry Based Learning terhadap Kemampuan Penalaran Siswa Kelas VII pada Materi Kalor. *Jurnal Pendidikan Fisika Indonesia*, 12(1): 19-25.

Daryanti, E. P., Rinanto, Y., & Dwiastuti, S. 2015. Peningkatan Kemampuan Penalaran Ilmiah melalui Model Pembelajaran Inkuiri Terbimbing pada Materi Sistem Pernapasan Manusia. *Jurnal Pendidikan Matematika dan Sains*, 3(2): 163-168.

Docktor, J. L., Strand, N. E., Mestre, J. P., & Ross, B. H. 2015. Conceptual Problem Solving in High School Physics. *Physics Education Research*, 11(2): 020106-1 – 020106-13.

Gotwals, A. W. & Songer, N. B. 2009. Reasoning Up and Down a Food Chain: Using an Assessment Framework to Investigate Student's Middle Knowledge. *Science Eduaction*, 94: 259-281.

Hermawanto, Kusairi, S., & Wartono. 2013. Pengaruh Blended Learning terhadap Penguasaan Konsep dan Penalaran Fisika Peserta Didik Kelas X. *Jurnal Pendidikan Fisika Indonesia*, 9: 67-76.

Hidayati, F. N., Akhsan, H., & Syuhendri. 2016. Identifikasi Miskonsepsi Siswa Kelas X pada Materi Elastisitas dan Hukum Hooke di SMA Negeri 1 Indralaya**.** *Jurnal Inovasi dan Pembelajaran Fisika,* 1-9 .

Kharida, L.A., Rusilowati, A., & Pratiknyo, K. 2009. Penerapan Model Pembelajaran Berbasis Masalah untuk Peningkatan Hasil Belajar Siswa pada Pokok Bahasan Elastisitas Bahan. *Jurnal Pendidikan Fisika Indonesia*, 5: 83-89.

Lawson, A. E. 1995. *Science Teaching and The Development of Thinking*. California: Wadsworth Publishing Company.

Lin, S. & Singh C. 2013. Using An Isomorphic Problem Pair to Learn Introductory Physics: Transferring from A Two-Step Problem to A Three-Step Problem. *Physical Review Special Topics - Physics Education Research*, 9: 1-21.

Nisa, S. L., Praswoto, S. H. B., & Setyowati, E. 2019. Identifikasi Miskonsepsi Elastisitas pada Siswa Kelas XI di SMA N 4 Jember. *FKIP e-PROCEEDING UNEJ*, ISSN : 2527 – 5917, Vol.4 No. 1.

Novia & Riandi. 2017. The Analysis of Students Scientific Reasoning Ability in Solving The Modified Lawson Classroom Test of Scientific Reasoning (MLCTSR) Problems by Applying The Levels of Inquiry. *Jurnal Pendidikan IPA Indonesia*, 6(1): 116-122.

Nurhayati, Yuliati, L., & Mufti, N. 2016. Pola Penalaran Ilmiah dan Kemampuan Penyelesaian Masalah Sintesis Fisika. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, 1(8): 1594-1597.

Setyono, A., Nugroho, S. E., & Yulianti, I. 2016. Analisis Kesulitan Siswa dalam Memecahkan Masalah Fisika Berbentuk Grafik. *Unnes Physics Education Journal*, 5(3): 32-39.

Shofiyah, N., Supardi, Z. A. I., & Jatmiko, B. 2013. Mengembangkan Penalaran Ilmiah (Scientific *Reasoning*) Siswa melalui Model Pembelajaran 5E pada Siswa Kelas X SMAN 15 Surabaya. *Jurnal Pendidikan IPA Indonesia*, 2(1): 83-87.

Singh, C. 2016. Interactive Video Tutorials for Enhancing Problem Solving, Reasoning, and Metacognitive Skills of Introductory Physics Students. *AIP Conference Proceedings*, 720(1): 177-180.

Snetinova, M. & Koupilova, Z. 2012. Student's Difficulties in Solving Physics Problems. *WDS'12* Proceedings *of Contributed Papers* Part III: 93-97.

Sujarwanto, E., Hidayat, A., & Wartono. 2014. Kemampuan Pemecahan Masalah Fisika Pada Modeling Instruction pada Siswa SMA Kelas XI. *Jurnal Pendidikan IPA Indonesia*, 3(1): 65-78.

Supiandi, M. I. & Julung, H. 2016. Pengaruh Model Problem Based Learning (PBL) terhadap Kemampuan Memecahkan Masalah dan Hasil Belajar Kognitif Siswa Biologi SMA. *Jurnal Pendidikan Sains*, 4(2): 60-64.

Syukri, M., Halim, L., & Meerah, T. S. M. 2012. Model Pendekatan Pakar Fisika dalam Menyelesaikan Masalah Fisika Kontekstual: Sebuah Studi Kasus. *Jurnal Pendidikan Fisika Indonesia*, 8: 61-67.

Wooley, J. S., Deal, A. M., & All, A. 2018. Undergraduate Students Demonstrate Common False Scientific Reasoning Strategies. *Thinking Skills and Creativity*, 27: 101-113.