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Student's Error in Solving Change and Relationship-PISA Problem and Its Scaffolding

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Abstract

Change and relationship problem is considered one of the most challenging PISA problems for students. This qualitative research aims to describe students' error in solving Change and Relationship-PISA problems in terms of self efficacy and the possible scaffolding. The subjects of this study were three students who had low, medium, and high self efficacy. The instrument used was a task-based interview in the form of Change and Relationship-PISA problems. The data were analyzed according to Newman's Error Analysis and Scaffolding by Anghileri. The results of this study show that students with low self-efficacy experienced error in transformation, proccess skills, and encoding. Students with medium self-efficacy experienced error in proccess skills and encoding. Students with high self-efficacy only met error in encoding. To overcome these error, students with low self-efficacy are given scaffolding in the form of reviewing, explaining, and restructuring. While students with medium and high self-efficacy are given scaffolding in the form of reviewing and restructuring only. Errors made by students in the problem solving process vary for each level of self efficacy, so that the way to overcome with scaffolding also needs to be adjusted.

Keywords: Change and relationship, error, PISA, scaffolding, self efficacy

Abstrak

Change and relationship dianggap sebagai salah satu masalah PISA yang paling menantang bagi siswa. Penelitian kualitatif ini bertujuan untuk mendeskripsikan kesalahan siswa dalam menyelesaikan masalah PISA konten change and relationship ditinjau dari self efficacy dan solusinya dengan scaffolding. Subjek penelitian ini adalah tiga siswa yang memiliki self efficacy rendah, sedang, dan tinggi. Instrumen yang digunakan adalah wawancara berbasis tugas berupa soal PISA konten change and relationship. Data pada penelitian ini dianalisis menggunakan indikator analisis kesalahan Newman dan scaffolding Anghileri. Hasil penelitian ini menunjukkan bahwa siswa dengan self efficacy rendah melakukan kesalahan dalam transformation, process skills, dan encoding. Siswa dengan self efficacy sedang melakukan kesalahan dalam process skills dan encoding. Siswa dengan self-efficacy tinggi menemui kesalahan dalam proses encoding. Untuk mengatasi kesalahan yang dilakukan, siswa dengan self efficacy rendah diberikan scaffolding dalam bentuk reviewing, explaining, dan restructuring. Sedangkan siswa dengan self efficacy sedang dan tinggi diberikan scaffolding dalam bentuk reviewing dan restructuring saja. Kesalahan yang dilakukan siswa dalam proses pemecahan masalah berbeda-beda untuk tiap tingkatan self efficacy, sehingga cara mengatasi dengan scaffolding pun perlu disesuaikan pula.

Kata kunci: Change and relationship, kesalahan, PISA, scaffolding, self efficacy

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Introduction

Change and relationship is one of the content in the Program for International Student Assessment (PISA) that considered one of the most challenging problems for students. PISA is designed to measure the reading, mathematics literacy, and science skills of 15-year-old students held by OECD every 3 years (Kastberg et al., 2015; Khaerunisak et al., 2017; Ozkale & Ozdemir Erdogan, 2022; She et al., 2018). Indonesia has participated in PISA since 2000 with unsatisfactory results in each participation. In the last PISA in 2018, Indonesia's score in mathematics was one of the lowest among other PISA participants, ranking 70 out of 77 participating countries (OECD, 2018).

Several research shows that in solving PISA questions, one of which is the Change and Relationship content, students still have difficulties and experiencing error (Ambarwati et al., 2018; Pranitasari & Ratu, 2020). Pranitasari & Ratu (2020) conducted research on students problem solving on change and relationship-PISA problem and conclude that most students makes error in understand the questions, write down the problem into mathematical model, and write down or conclude the final results. Ambarwati et al. (2018) in their research also stated that the lack of basic knowledge was a causal factor that greatly influenced student error in working on Change and Relationship-PISA problem, in which most of the students experience error in understanding and using concepts. However, the research that has been done only discusses the description of students' error in solving PISA questions and has not revealed efforts to overcome these error.

Errors are the main source of knowing students' difficulties in solving problems (Zanthy & Maulani, 2020). Error is seen as a mistake in proccess of solving mathematical problem systematically, through algorithms, procedures, or any other method (Arhin & Hokor, 2021; Mulungye et al., 2016). One of the error analysis in problem solving was error analysis proposed by Newman. Newman's error analysis presents a popular approach that can be used to investigate mistakes experienced by students when solving the problem (Alhassora et al., 2017; Noutsara et al., 2021; Sumule et al., 2018). There are five errors in solving the problem proposed by Newman, namely reading error, comprehension error, transformation error, proccess skills error, and encoding error.

The solution that can overcome students' error in solving PISA problems is scaffolding. Scaffolding is a process of providing assistance or guide for students in order to help them to solve certain problems which would be beyond their unassisted efforts and slowly the scope and amount of scaffolding will be reduced gradually until the student able to solve problems on their own (Anghileri, 2006; Bakker et al., 2015; Cho & Kim, 2020; Haataja et al., 2019). Anghileri (2006) suggests three levels of scaffolding as a set of effective teaching strategies to overcome students difficulities. The first level is environmental provisions, the second level are explaining, reviewing and restructuring, and the highest level of scaffolding is developing conceptual thinking. This research will focused on the second level of scaffolding which is explaining, reviewing, and restructuring.

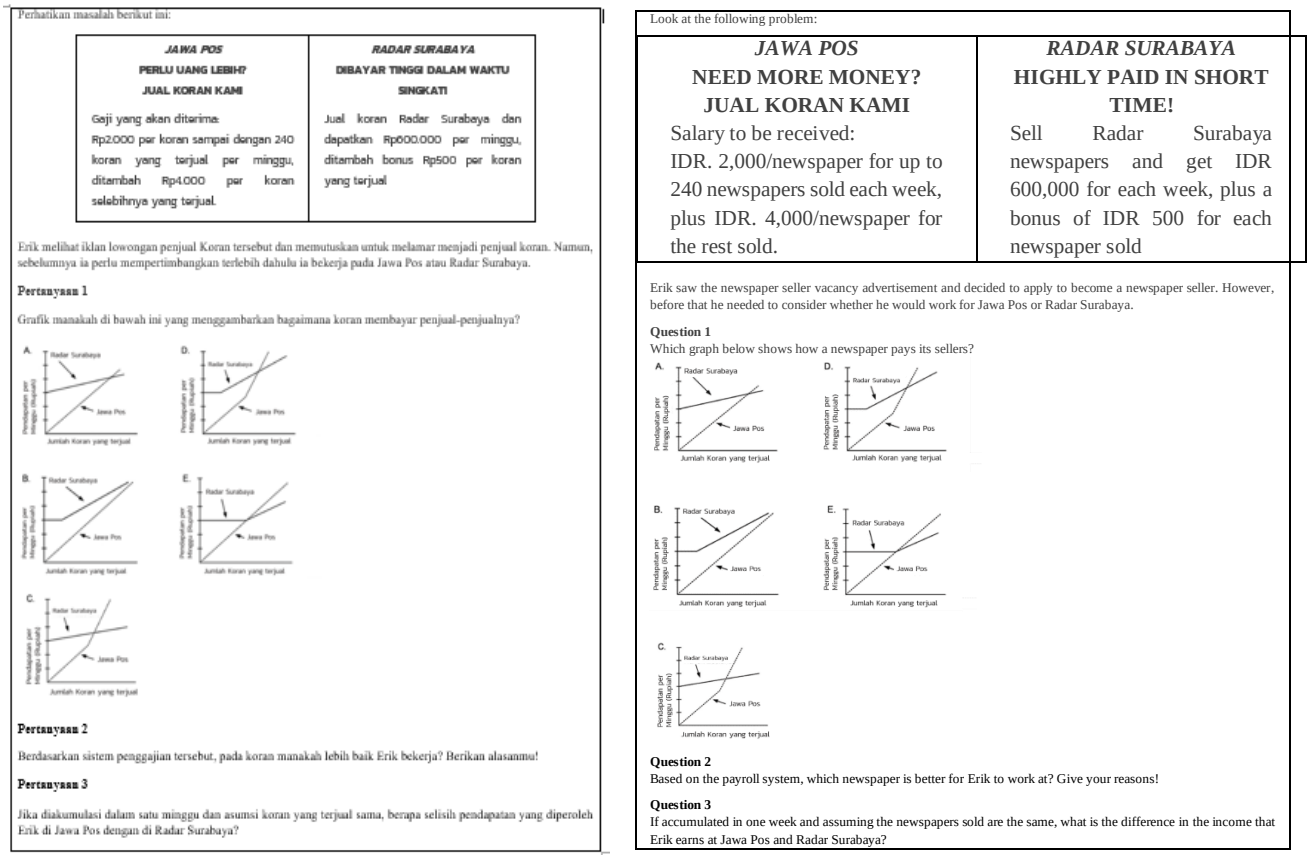
The level of error made by students can be reduced by a high level of self-efficacy. Self-efficacy in problem solving is students' confidence, belief, or self-assessment in their ability in three dimensions which are magnitude, generality and strength that they will able to solve the problem (Loviasari & Mampouw, 2022; Masitoh & Fitriyani, 2018; Simamora et al., 2018). The higher the self-efficacy of students, the easier it is for students to solve mathematical problems (Rokhmatillah et al., 2021; Somawati, 2018). Aside from motivation and achievement, self-efficacy have an influence in mathematics success and failure (Utami & Wutsqa, 2017). However, there has not been an in-depth study of student's error in solving PISA problems viewed from self-efficacy and the scaffolding given, even though this is important to do because the error experienced by students with different self-efficacy are not the same and the scaffolding given to each student is different. Based on the description above, this study aims to describe students' error in solving change and relationship-PISA problem and the possibble scaffolding.

Method

This research was descriptive qualitative research. Subjects of this research were three students on grade 10th who selected from seven students who had given self efficacy questionnaire adapted from Schwarzer & Jerusalem (1995). As many as 10 question item General Self Efficacy questionnaire adopted from Schwarzer & Jerusalem (1995) given to the students. After that, students with various self efficacy participated a test consisting of three question examining their abilities in solving Change and Relationship-PISA problem. They were also told that their work will not be graded so they can use their

own strategies to solve the problem. The results of the questionnaire informed that the participants had different self efficacy categories, namely students with low self efficacy, students with medium self efficacy, and students with high self efficacy. As many as one samples were recruited from each of those three categories. Thus, we had one student with low self efficacy (code as LS), one student with medium self efficacy (code as MS), and one student with high self efficacy (code as HS).

Data were collected from the subject's work on change and relationship-PISA problem solving test and the result of questionnaire. The instruments have been validated by experts. Semi-open interviews were conducted to explore the subject's difficulties in solving change and relationship-PISA problem and provide scaffolding to the sample according to what each sample needed.



Perhatikan masalah berikut ini:

JAWA POS PERLU UANG LEBIH? JUAL KORAN KAMI	RADAR SURABAYA DIBAYAR TINGGI DALAM WAKTU SINGKATI
Gaji yang akan diterima: Rp2.000 per koran sampai dengan 240 koran yang terjual per minggu, ditambah Rp4.000 per koran selebihnya yang terjual.	Jual koran Radar Surabaya dan dapatkan Rp600.000 per minggu, ditambah bonus Rp500 per koran yang terjual

Erik melihat iklan lowongan penjual Koran tersebut dan memutuskan untuk melamar menjadi penjual koran. Namun, sebelumnya ia perlu mempertimbangkan terlebih dahulu ia bekerja pada Jawa Pos atau Radar Surabaya.

Pertanyaan 1

Grafik manakah di bawah ini yang menggambarkan bagaimana koran membayar penjual-penjualnya?

A. B. C. D. E.

Radar Surabaya
Jawa Pos
Pendapatan per Minggu (Rupiah)
Jumlah Koran yang terjual

Pertanyaan 2

Berdasarkan sistem penggajian tersebut, pada koran manakah lebih baik Erik bekerja? Berikan alasanmu!

Pertanyaan 3

Jika diakumulasi dalam satu minggu dan asumsi koran yang terjual sama, berapa selisih pendapatan yang diperoleh Erik di Jawa Pos dengan di Radar Surabaya?

Look at the following problem:

JAWA POS NEED MORE MONEY? JUAL KORAN KAMI	*RADAR SURABAYA* HIGHLY PAID IN SHORT TIME!
Salary to be received: IDR. 2,000/newspaper for up to 240 newspapers sold each week, plus IDR. 4,000/newspaper for the rest sold.	Sell Radar Surabaya newspapers and get IDR 600,000 for each week, plus a bonus of IDR 500 for each newspaper sold

Erik saw the newspaper seller vacancy advertisement and decided to apply to become a newspaper seller. However, before that he needed to consider whether he would work for Jawa Pos or Radar Surabaya.

Question 1

Which graph below shows how a newspaper pays its sellers?

A. B. C. D. E.

Radar Surabaya
Jawa Pos
Pendapatan per Minggu (Rupiah)
Jumlah Koran yang terjual

Question 2

Based on the payroll system, which newspaper is better for Erik to work at? Give your reasons!

Question 3

If accumulated in one week and assuming the newspapers sold are the same, what is the difference in the income that Erik earns at Jawa Pos and Radar Surabaya?

Figure 1. PISA test instrument

The data were analysed were analyzed according to Newman's error analysis adopted from Rohmah & Sutiarso (2018) as follows:

Table 1. Newman's Error Analysis

Stage Analysis Newman	Space below
Reading error (RE)	Identify information and mathematical symbols with complete
Comprehension error (CE)	Write down what is known and asked a question on demand
Transformation error (TE)	Write down the mathematical model correctly
Proccess skilss error (PE)	Using a particular procedure right and the answer is true
Encoding error (EE)	The conclusion is rendered right

The scaffolding indicators used are the scaffolding indicators adapted from Anghileri (2006) as follows:

Table 2. Scaffolding in Problem Solving

Scaffolding Steps	Component of Scaffolding
Reviewing	Looking, touching, & verbalizing
	Prompting and probing
	Parallel modelling
	Students explaining and justifying
	Interpreting student's actions and talk
Explaining	Showing and telling
	Teacher explaining
Restructuring	Re-phrasing students' task
	Negotiating meanings
	Simplifying the problem
	Providing meaningful context

Result and Discussion

Problem Solving and Scaffolding of Student with Low Self Efficacy

Based on the results of the answers to the tests of change and relationship problem and interviews that have been carried out to the subject, namely LS, subjects meet some error in solving the problem. The following is the result of LS's answer in solving the Change and Relationship-PISA problem.

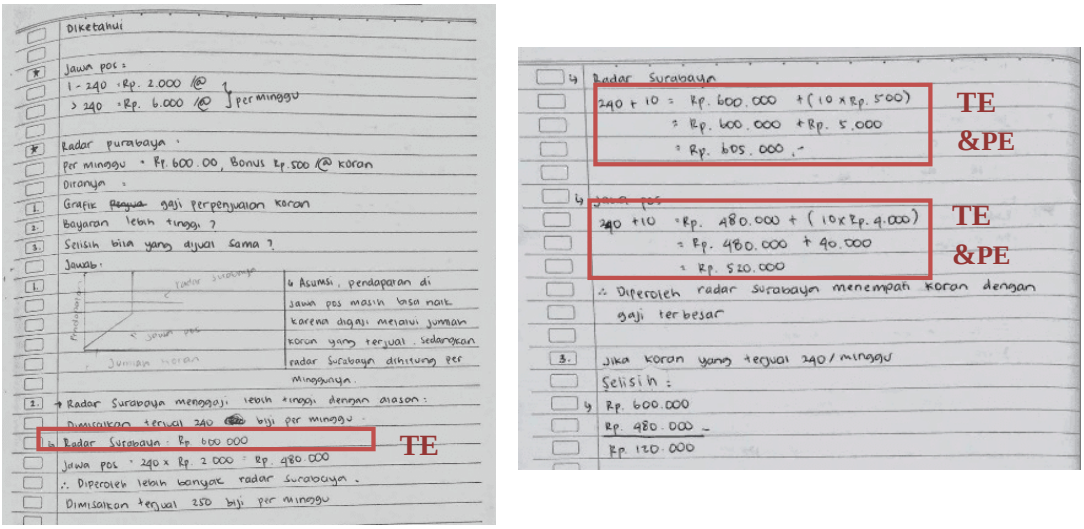


Figure 2. LS' answer in solving the problem before scaffolding

Based on Figure 2, it can be seen that LS is able to absorb the information properly and able to write down the known and asked information from the problem, indicated that LS didn't meet any reading and comprehension error. However, LS experienced transformation error which made LS not able to write down the mathematical model incorrectly for both Radar Surabaya and Jawa Pos salary. This occurred because LS is not careful in identified the detail information which make LS not use the proper information to solve the problem given. As a result, LS does not come up with the right solution to the problem, which indicated LS to experienced proccess skills error. This is inline with research conducted by Hadi et al. (2018) who stated that due to transformation error, students didn't able to find the right solution to the problem. Noutsara et al. (2021) in their research also explained that students sometimes makes mistake in transformation and does not write the correct formula so that the result of

the answer operation obtained is incorrect and does not correspond to what is asked on the question. Students with low self efficacy also met error in encoding, because students come up with the wrong solution.

Errors made by LS in transformation and process skills caused by the carelessness in looking at the information. Therefore, the second level of scaffolding in the form of reviewing, explaining, and restructuring was given to LS with the aim of overcoming those errors. First, LS was given scaffolding in the form of reviewing by being asked to re-read the problem and then asked to explain again what she understood from the problem. LS was given scaffolding in the form of restructuring by doing question and answers method for compiling and rebuilding knowledge about the increase of the income. Explaining how the amount of newspaper will affect the salary also be one of the scaffolding given to the student. By writing the correct mathematical model, then automatically LS has also overcome the error in proccess skills.

R01 : Apart from information about the fixed income which is 600,000, what does it say there for the Radar Surabaya newspaper? *(Reviewing)*

LS01 : There says that Radar Surabaya gives bonus income 500 for each newspaper.

R02 : It means what will happen to the income? *(Restructuring)*

(LS is in silence for some minutes)

R03 : There say Radar Surabaya gives bonus income for each newspaper. So the value of Radar Surabaya salary always depend on the amount of newspaper that is substituted. So the income increases 500 for each of newspaper sold. *(Explaining)*

LS03 : Oh okay, I got it. First I think that the bonus given when the newspaper sold is more than 240.

R04 : How about Jawa Pos? Are you sure you didn't make any mistake? *(Reviewing)*

LS04 : I don't think I make any mistake, because I already add the bonus 4,000.

R05 : Are you sure about the amount of bonus? Try to read the problem again. *(Reviewing)*

LS05 : Oh, I see. It should be 6,000 not 4,000, because the regular salary is 2,000 and the bonus is 4,000.

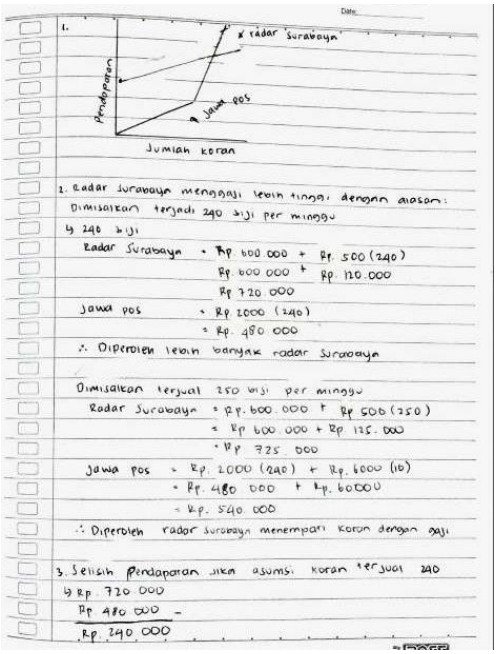


Figure 3. MS' answer in proccess skills after scaffolding

The blue marks in Figure 3 showed the correction of the error made by LS before. After the first scaffolding, LS wrote the mathematical equation without any notation. Therefore, LS was given

scaffolding to direct her to write the appropriate notation in the mathematical model. To overcome LS' error in transformation, scaffolding in the form of reviewing and restructuring was given to LS with the aim of helping LS write the notation of mathematical model correctly.

R06 : Don't you know what mathematics model used to solve the problem? *(Reviewing)*

LS06 : I'm not sure.

R07 : Do you remember about function? *(Reviewing)*

LS07 : Mmm yes, I remember a little bit about it. But I don't think this problem can be solved with functions.

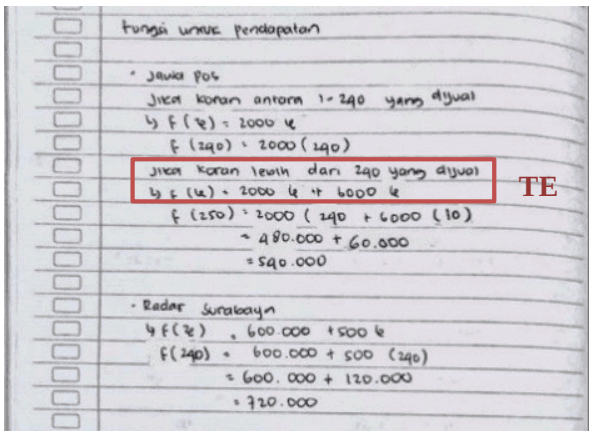
R08 : Why do you think it can be solved with function? *(Reviewing)*

LS08 : Because if it's a function then the formula is $ax + by = c$. But here the only variable is the newspaper.

R09 : Are you sure the formula is $ax + by = c$? Then what is x and y there? *(Restructuring)*

LS09 : Am I wrong? As long as I remember, the formula for the function is $ax + by = c$. But there is only newspaper, if newspaper is x, I don't know what is y.

R05 : You said before that you only found one variable which is newspaper. Then why don't you try to remember the formula of the function with one variable only? *(Restructuring)*



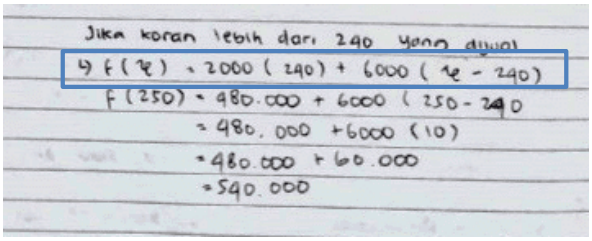
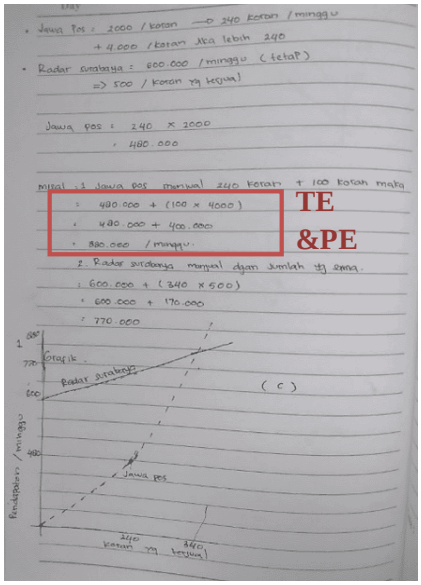


Figure 4. LS answer in transformation after the scaffolding

The blue marks in Figure 4 showed the correction of the error made by LS before. After the scaffolding given, LS have some trial and error to found the correct notation of mathematical model as showed in Figure 4. LS still makes an error in determining the function formula of Jawa Pos if more than 240 newspapers were sold. Therefore, scaffolding in the form of reviewing is given to LS by asking LS to compare the model he had written with the calculations LS made before to find the correct mathematical model of the problem. As a result, LS had written the correct mathematical model of the Jawa Pos problem. The improvement of the answer made by LS made him fulfill the encoding indicator, he correctly stated the conclusion of the answer obtained verbally.

Problem Solving and Scaffolding of Student with Medium Self Efficacy

Based on the results of the answers to the tests of change and relationship problem and interviews that have been carried out to the subject, namely MS, subjects meet some error in solving the problem. The following are the results of MS's answers in solving the Change and Relationship-PISA content problem.



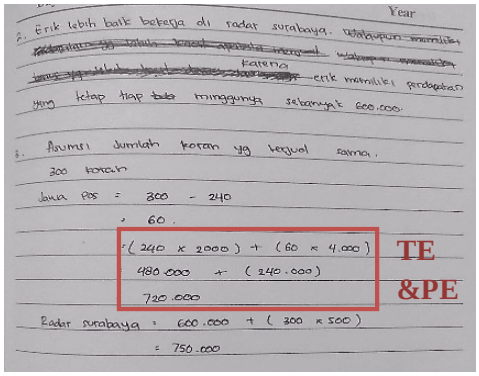


Figure 5. MS' answer in solving the problem before scaffolding

Based on the answers in Figure 6, MS didn't meet any reading and comprehension error by write down what was known and was able to mention what was asked from the problem verbally. However, later it found that MS experienced proccess skills error because MS does not use the detail of the information of bonus 6,000 for each of newspaper if more than 240 sold at Jawa Pos to solve the problem. It can be seen that MS used 4,000 for the bonus instead of 6,000. As a result, MS didn't found the correct answer of the salary at Jawa Pos. This is in line with research conducted by Fitriani et al. (2018) which stated that one of the factors that made the process skill errors occurred because students were correct using the concepts to solve the problem, but not doing the right thing in calculation solve the problem. Although MS did not write the notation, it can be seen that MS did not experienced any transformation error by writing the correct mathematical model of the problem. MS also experienced the encoding error because MS come up with the wrong solution. One of the factor students did not able to fulfill encoding indicator is mistakes made by students when writing the final answer (Noutsara et al., 2021).

The errors made by MS in proccess skills caused by MS carelessness in using the detail information to solve the problem. To overcome those errors, scaffolding in the form of reviewing was given by being asked to re-read the problem so that she could highlight the details of the question that the salary if more than 240 newspapers are sold at Radar Surabaya is 6,000 not 4,000.

R01 : When more than 240 were sold, how much Radar Surabaya pays them? *(Reviewing)*
MS01 : 4,000.
R02 : Take a look and try to understand the problem again. *(Reviewing)*
MS02 : Oh! It will be added 4,000, that means 4,000 plus 2,000 is 6,000.
R03 : It means that there was something wrong in your answer earlier? *(Reviewing)*
MS03 : Yes its wrong, because I wrote 4,000 not 6,000.

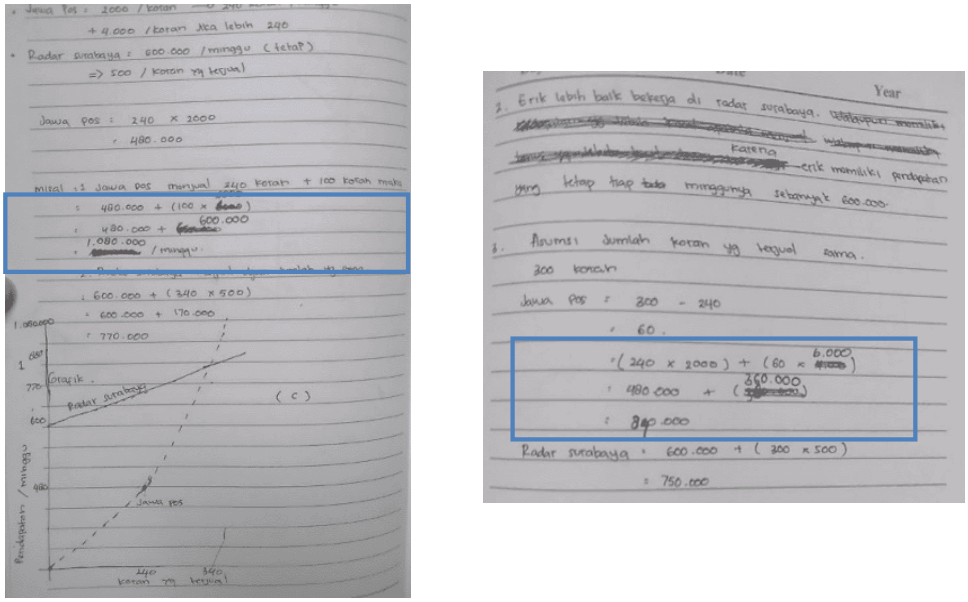


Figure 6. MS' answer in proccess skill after the scaffolding

The blue marks in Figure 4 showed the correction of the error made by MS before. Actually MS did not meet any transformation error, but to get more complete answer MS was asked to write the mathematical model in the form of notation. Therefore, scaffolding also given to MS in the form of reviewing and restructuring to help MS write the correct notation and mathematical concepts from the problem.

P04 : Try to remember again. In this problem, the salary is depend on what? *(Restructuring)*
MS04 : It based on how many newspapers sold.
P05 : That's right. The salary depends on a value. Try to remember again what material or concepts in mathematics is it? *(Reviewing)*
MS05 : Oh, isn't that one-variable linear equation?
P06 : Why do you think it is one-variable linear equation? *(Reviewing)*
MS06 : Because there is only on variable.
P07 : But in one-variable linear equation, the equation is equals a value right? But in this problem is it already given a value on the other side? *(Restructuring)*
MS07 : Oh, I remember. Is it function?.
P08 : Yes, it's kind of function. Try to write the mathematical model of the problem. *(Reviewing)*

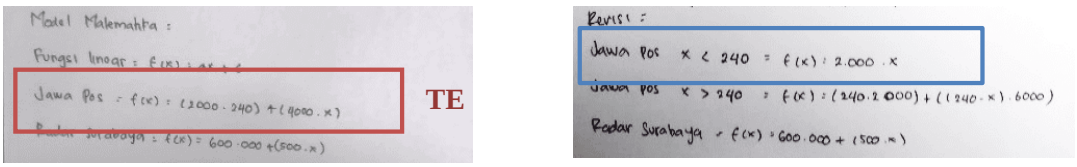


Figure 7. MS' answer in transformation after the scaffolding

The blue marks in Figure 4 showed the correction of the error made by MS before. From Figure 7, it can be seen that MS still made error in writing the mathematical model for Jawa Pos salary when the newspapers sold more than 240. Therefore, the scaffolding review stage was carried out so that MS could find the correct mathematical model for all linear functions. The scaffolding provided has led MS to the correct problem solution. As a result, MS automatically fulfilled the encoding indicator by making conclusion from the correct solution that she had done before.

Problem Solving and Scaffolding of Student with High Self Efficacy

Based on the results of the answers to the tests of change and relationship problem and interviews

that have been carried out to the subject, namely HS, subjects did not meet any error until come up with the solution. The following is the result of HS's answer in solving the Change and Relationship-PISA problem.

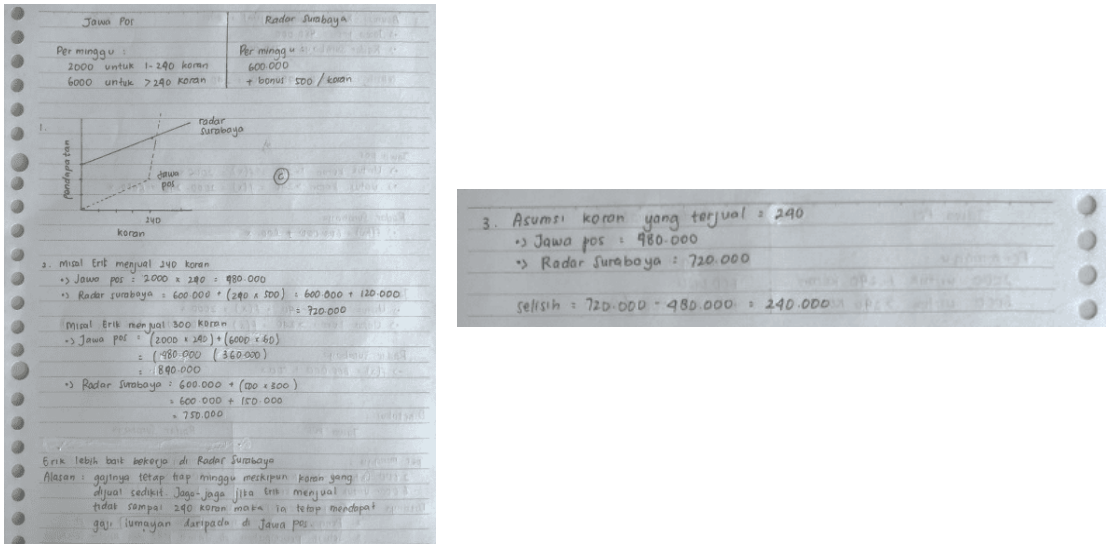


Figure 8. HS' answer in solving the problem

HS didn't meet any of reading and comprehension error. HS was able to read and absorb the information well, caused him to wrote down what was known and was able to mention what was asked from the problem verbally. HS also has fulfilled the indicator of transformation by write down the correct mathematical model of Jawa Pos and Radar Surabaya salary although without using any notation. The error HS didn't experienced in the previous stage make HS also fulfilled process skills and did not make any errors. This led HS to have the correct solution of the problem. Marasabessy (2020) stated that students with high self-efficacy more easily and successfully surpass the exercises given to them, so that the final results of the learning which are reflected in their academic achievement also tend to be higher than students who have low self-efficacy. However, HS did not fulfill the encoding indicator because he was not used to drawing conclusions after solving the problem.

Actually, HS has already solving the problem without any error in transformation, but to get a more complete answer, HS was asked to write the mathematical model in the form of notation. Therefore, scaffolding in the form of reviewing and restructuring was given to HS to help HS write the correct notation and mathematical concepts from the problem. HS was asked what possible concept used in solving the problem and asked to write down the model of those concept. HS made a mistake in remembering the concept used to solve the problem so he mentioned the concept of linear equation of one variable. Therefore, scaffolding in the form of restructuring was carried out by asking questions about the mathematical model of one variable linear equation that could lead HS to realize that the model presented was not suitable for use in the given problem.

P01 : Try to remember if the linear equation of one variable means what does it look like? *(Restructuring)*

HS01 : For example, the function 2x, the variables are only x, not y or z.

P02 : 2x is equated with what? *(Restructuring)*

HS02 : With zero?

P03 : With a number or a constant, right? But in this case, is it equated with zero or a constant? *(Restructuring)*

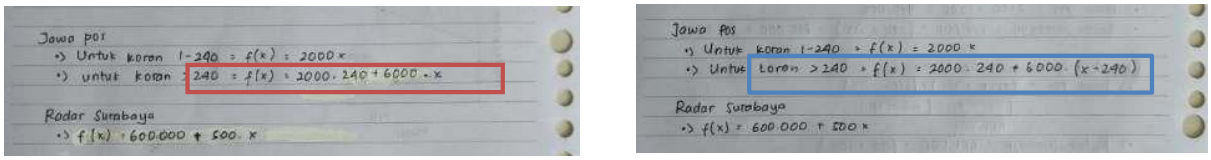


Figure 9. HS answer on modelling the problem after scaffolding

From Figure 9, it can be seen that after the scaffolding given, there were still errors made by HS in write down the model of Salary at Jawa Pos, which HS write down that 6,000 was bonus for all newspaper sold instead for the number of newspapers sold when it is more than 240 newspapers. Therefore, scaffolding in the form of reviewing was given by asking HS to compare the mathematical model he wrote with the problem solving he had done before. As a result, HS realized his mistake and wrote the correct mathematical model. The blue marks in Figure 4 showed the correction of the error made by MS before. To overcome the encoding errors, scaffolding in the form of reviewing also given to ask students make a conclusion after solving the problem. This is in line with the Kaka et al (2018) research results that if the subject experiences errors in carrying out planning, then the scaffolding given is to ask the subject to pay attention to mathematical concepts and be careful in operating algebra.

Conclusion

This study found that the kind of errors made by students is different for each of the self efficacy level. Student with low self-efficacy experienced errors in transformation, proccess skills, and encoding. The transformation and proccess skills errors occur because their carelessness in using the detail of information. The error experienced in previous stage made students with low self efficacy also met error in encoding because the solution obtained in problem solving is wrong. To overcome the errors experienced by students with low self efficacy, scaffolding in the form of reviewing, explaining, and restructuring are given. Student with medium self-efficacy experienced error in process skills and encoding. Proccess skill errors occur because students did not giving enough attention to the detail of the information which made them to have incorrect solution. Students with medium self efficacy have experienced error in encoding because they are not accustomed to doing it after solving the problem. To overcome the errors experienced by students with medium self efficacy, scaffolding in the form of reviewing and restructuring are given.

Students with high self-efficacy experienced encoding error. This error occur because they were not used to giving a conclusion after solving the problem. Students with high self efficacy did not experience any errors in reading, comprehension, transformation, and proccess skills that led them to find the correct solution. However, students with high self efficacy did not write the complete mathematical model in the form of notation, so to overcome the errors experienced by students with high self efficacy, scaffolding in the form of reviewing and restructuring are given. Students with low, medium, and high self efficacy have different abilities and errors in solving problems so the teachers are suggested to provide scaffolding to overcame the errors experienced by students so that later errors do not happen again. To get a more in-depth analysis of student errors in PISA problems, further research needs to be done to analyze student errors in other content of PISA problems. Further research is also needed to find suitable ways of learning in order to reduce students' errors in solving problems, especially PISA problems.

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