How to Create Isomorphic Example-Problem Pairs for Facilitating Analogical Thinking

F M Pastoriko\textsuperscript{1,}\textsuperscript{*} and E Retnowati\textsuperscript{2}

\textsuperscript{1}Graduate School of Mathematics Education, Universitas Negeri Yogyakarta, Indonesia
\textsuperscript{2}Department of Mathematics Education, Faculty of Mathematics and Science, Universitas Negeri Yogyakarta, Indonesia

Corresponding author: fransiskuspastoriko@gmail.com, fransiskusmagnis.2018@student.uny.ac.id

Abstract. Worked-example and problem-solving are often paired and named as the example-problem learning method. This learning method is often recommended by cognitive load theorists, but not much thought has been given to what kind of problems should be used as the example-problem pairs. If there is no clear specification in using the method, as a result, there might be little to no improvement in students' problem-solving ability. Particularly, the improvement of analogical thinking can be set as the goal of learning. Analogy comes when students can relate to their previous knowledge to solve new problems. In the example-problem learning method, the example can be acquired first and then regarded as the prior knowledge for students to solve the subsequent problem. As analogy is one of the problem-solving strategies, ultimately mastering analogy strategy can improve problem-solving ability. The problem is, analogy does not come naturally, hence a careful consideration about what kind of problems used during instruction is needed. In this paper, we propose the use of isomorphic problems—problems with the same solution procedures—in choosing the example-problem pair. We choose isomorphic problems because it suits example-problems learning and it is focused on improving student’s analogical thinking. We also propose the procedure in using the isomorphic problems.

1. Introduction
All people without any exception have the innate problem-solving ability. We solve problems almost in every aspect of our life, ranging from dealing simple problem like a flat tire to the complex situation like accomplishing a job. Because problems are part of our life, we need to understand the problems that we want to solve and what makes it difficult [1]. In consequence, it is important to improve our problem-solving ability. Not only it makes our personal life better, but good problem-solving skill also important for professional life. Of course, the opposite applies; poor problem-solving ability will only lead to difficulties. By knowing how good or poor our problem-solving ability is, we can get a good understanding of how we are going to improve it.

There is a lot of ways to improve problem-solving ability. For children, formal education is one of the most common ways to improve it. As it stands, one of the most crucial results that students ought to achieve after graduating from their respective educations is to have good problem-solving abilities. Mathematics problem-solving ability, in particular, is quite important because we use mathematics almost daily. Unfortunately, international studies such as PISA and TIMSS, and also some local research show that students in Indonesia do not have good enough mathematics problem-solving ability [2–4].
Students may tackle simple problems in their life successfully, but dealing with a complex problem like solving problems in—and using—mathematics is an entirely different matter.

This unfortunate result does not mean there is no effort to improve Indonesian students’ problem-solving ability. In fact, there are many kinds of research done regarding problem-solving, such as analyzing students’ difficulties (e.g., [5]), analyzing suitable method or model (e.g., [6]), and developing material for improving problem-solving ability (e.g., [7]). Hence the implication of result shown by the research is, despite many studies have already been conducted, they are never enough. Further research to improve Indonesian students—and the others—is always welcome because improving problem-solving ability is not easy; it takes a systemic effort.

The previously mentioned researches show we need particular strategies, models, or methods which are suitable for improving students problem-solving ability. Among the many learning methods to improve students’ problem-solving ability, worked-example and problem-solving strategies are quite popular. Problem-solving learning method refers to the learning process where the students are given minimal guidance to solve problems given by the teacher during solving and learning the problem solution [8]. Meanwhile, worked-example learning method refers to the learning process where students are shown a step-by-step solution to a problem to be acquired and this is often categorized as an explicit instruction [9]. Between the two methods, no method is superior to the others when given to the students with a suitable level of the knowledge base. Instead, the two methods can be paired during the learning phase in an example-problem pairs learning method. In this learning method, students first study an example provided with the step-by-step solution (worked-example). After that, they immediately attempt to solve an ‘equivalent problem’ (problem-solving) [10]. We use this instructional presentation method, as exemplified in this paper because example-problem learning method has been proved to be more effective than problem-solving only through may experimental studies in cognitive load theory [11–13].

Even though example-problem learning method is already used extensively in the cognitive load theory research, usually there is no clear explanation in how the example-problem pairs are chosen. Thus, it may be challenging for the teachers who sought to implement the method in the real classroom. As mentioned above, the example-problem pairs created must be chosen carefully with a clear goal of learning. One of the goals that can be reached by using example-problem learning method is improving students’ analogical thinking, i.e. how they use analogy as a problem-solving strategy. Analogy as a strategy to solve problems is closely related to example-problem learning method.

In the following, we present our systematic literature review focusing on the use of isomorphic problems to make the example-problem pair. We identify, select, critically appraise, and synthesize some research in order to answer, “How to create isomorphic example-problem pairs for facilitating analogical thinking?”

2. Isomorphism in Solving Problems

In the simplest term, problem-solving is a process to solve a problem. Problem-solving ability (or skill) can also be defined as an ability to formulate a variety of unique ways to solve a problem [14]. It means that a student can have a different way to answer a question with their peers as long as the method is correct and logically accepted. To solve a problem, Polya’s heuristic (general strategy) may be used [15]. First, we have to understand the problem; we have to see clearly what is required. Second, we have to see how the various items are connected, how the unknown is linked to the data, in order to obtain the idea of the solution, to make a plan. Third, we carry out our plan. Fourth, we look back at the completed solution, we review and discuss it.

As shown in Polya’s heuristic, the strategies are rather general. The examples of specific strategies in solving mathematics problems are creating a diagram, guessing and checking, using a table or making a list, using logical reasoning, finding a pattern, working backward, and solving an easier version [16]. Nevertheless, more specific strategies in solving mathematics are those related directly to the underlying concepts of the problem. For example, given a problem about the height of a tree and the elevation angle. Then, more specific strategy to solve this kind of problem is the trigonometry ratio. Without this
conceptual knowledge, applying the general problem-solving strategy might remain an inefficient solution.

In their research, Chan [17] found that 'analogy' is also one of the strategies to solve problems. An analogy is a cognitive process which maps a base (source of knowledge) to a target (a problem or current domain of knowledge) [18]. By using an analogy, students can solve new problems by using their prior knowledge/experience [19]. In analogy thinking, a problem solver maps the structure of the to-be-solved problem with a similar problem solution that has been learned previously.

Indeed, analogy thinking needs to be learned as it does not evolve naturally to our mind. A novice student often fails to make use of their prior knowledge spontaneously if the problems they encountered are different from their prior knowledge in terms of superficial details. In other words, they will only use their prior knowledge if they have been told to consider it [20–23]. As a consequence, teachers have to teach them how to use analogy and make them get used to it.

One way to do it might be by integrating isomorphism to example-problem learning method. Isomorphism is about how two situations (or in the specific case, problems) closely related. Example-problem learning method allows the students to do analogy and vice versa because they know the problems they need to solve are somewhat equivalent to the example provided. They know that they can make use of the base (in this case, the example) to solve the problem. According to Sweller [12], by working on a similar problem immediately after reading a worked example, their motivation will be increased because it allows them to be able to have more cognitive activity. It should be noted that example should be given before the problem, as the reverse order did not lead to better learning than problem-solving only [24].

Greer [25] divided isomorphism into three levels, that is surface isomorphism, deep isomorphism, and mediated isomorphism. Surface isomorphism occurs when the subject sees two specific situations, namely $S_1$ and $S_2$, and establishes a simple isomorphism by representing $S_1$ as $S_2$ or vice versa. Deep isomorphism occurs when the subject sees two specific situations, $S_1$ and $S_2$, and establishes an isomorphism by using a different kind of reasoning. Mediated isomorphism occurs when the subject sees two specific situations, $S_1$ and $S_2$, as special cases of $S$, whereby she establishes an isomorphism between $S_1$ and $S_2$.

Our focus is not the isomorphisms themselves, but instead on isomorphic problems. Isomorphic problems refer to the problems with the same solution procedure or structure [25]. As isomorphic problems have the same solution procedure, we can easily map isomorphism between the problems. In the next two subsections, we will give the example of isomorphic problems in surface and deep isomorphism. We argue that isomorphic problems in mediated isomorphism are the least suitable for example-problem learning method.

2.1. Surface Isomorphism

The key of surface isomorphism is the ‘easy-to-see’ relationship between two problems. An example of surface isomorphism can be seen from two problems with exactly the same context, but different quantities. Problem 1 and problem 2 are an example of isomorphic problems in surface isomorphism.

- **Problem 1** The height of building $A$ is 9.78 meter. If the house next to it has 0.26 times the height of building $A$, how tall is the house?
- **Problem 2** The height of building $A$ is 10 meters. If the house next to it has 2 times the height of building $A$, how tall is the house?

One of the uses of surface isomorphism is to deal with 'nasty' numbers. Greer [25] gave three steps to deal with 'nasty' numbers by using surface isomorphism.

- Replace the 'nasty' numbers with 'friendly' numbers.
- Solve the problem with the 'friendly' numbers.
- Transform back your solution to the problem with the 'nasty' numbers.

Consider Problem 1 and Problem 2 above. For novice learners, problem 1 can be considered difficult to solve because of the 'nasty' numbers (i.e., 9.78; 0.26). However, students can map this question into the easier version (Problem 2) by changing the nasty numbers to whole numbers. By using an analogy,
students will realize that because the problems are the same (except the quantities), the solution procedure must also be the same. Students need to learn the variable and quantity involved in the problem. This could lead them to understand the relation between variables that evoke a certain context and introduce the conceptual knowledge underlying the problem. Being presented isomorphism problems repeatedly may also assist learners to automate their analogical thinking.

2.2. Deep Isomorphism
Greer’s deep isomorphism has the same concept as the general definition of isomorphism gave by Reed [26]. Isomorphic problems in deep format provide varied contexts, but they have the same solution procedure. The stories have different context if they fall into different categories in taxonomies (for further reading, see [27]). The main characteristic of deep isomorphism is the use of different reasoning to view the isomorphism. Consider the following example.

- **Problem 3** A bank sets a deposit rate of 5% per year. If after depositing his money for a year, Andi’s money now is Rp 10,500,000.00, find Andi’s initial deposit!
- **Solution 1** Suppose Andi’s initial deposit is \( x \) in rupiah. Because the rate is 5% a year and Andi deposited his money for a year, the interest he got is \( 5\% \times x = 5x/100 \).
  Hence his money now in \( x \) is \( x + 5x/100 = 105x/100 \).
  We get the equality \( 105x/100 = 10,500,000 \).
  Now we solve for \( x \).
  \[
  105x/100 = 10,500,000 \\
  105x = 10,500,000 \times 100 \\
  x = (10,500,000 \times 100) / 105 \\
  x = 10,000,000 
  \]
  So, Andi’s initial deposit is Rp 10,000,000.00.

Now consider the following problem.

- **Problem 4** A chemist mixes \( x \) liter of liquid A and \( 0.1x \) liter of liquid B. If the mixture produced is 11 liter, find the amount of liquid A!
To solve the problem, first we make equation \( x + x/100 = 101x/100 \). Because the mixture produced is 11 liter, we get \( 101x/100 = 11 \). After that, we solve the equation for \( x \). This solution procedure is exactly the same as the solution for problem 3.

Problem 3 and Problem 4 is an example of isomorphic problems in deep isomorphism.

3. Discussion
As mentioned in section 2, analogical thinking may be learned. When solving new problems, students tend to use an analogy if they are told to do so [28]. It implies that to optimize students’ analogy process, they need to be trained to see the relationship between the problems. As mentioned in the previous section, example–problem pairs can be utilized to help the student. By instructing novice students to get used to learning the relationship between the example and the paired problem, the students’ mind is expected to be automated to using their prior knowledge to solve problems.

Choosing the problems for the example–problem pairs needs careful consideration. We propose the use of isomorphic problems in example–problem pairs, for two reasons. First, isomorphic problems have exactly the same solution procedure, which is suitable for example–problem pairs; second, isomorphic problems help students to see the relationship between problems. They also may contain entirely different contexts that will assist students to develop their analogical thinking, thus improving their problem-solving ability.

After they get used to isomorphic problems, students can apply isomorphism to solve problems, for an instance in dealing with ‘nasty’ number. In a more advanced application, they can change the problem into another form that has an easier solution procedure. However, isomorphism is not limited to problems on the same topic. Undoubtedly, they can be used to recall old topics related to the current topic when available.
Cognitive load theory provides some principles for creating the pairs (see [9,10,29]). These can be explained below.

- The example should be presented in easy to understand and the solution provided by the teacher must be as clear as possible therefore can be followed thoroughly without wasting cognitive load.
- Surface isomorphism may be relevant for beginner students. If word problems are used, the example and problem should have the same context. If not, the wording presentation must be obviously similar.
- For deep isomorphism, if the word problems are used, the example and problem should have a varied context. The relationship between the example and the problem must be more difficult to see and need careful attention.
- The quantities involved in the problem pair are not necessarily the same or different, but the focus of learning should be clear, that is the acquisition of the underlying knowledge.
- The problem should have exactly the same solution procedure with the example. This is aimed to facilitate knowledge automation significant to the development of analogical thinking.
- The example-problem pairs are presented in the worksheet in such a way students do not see the example when trying to solve the paired problems. Verbatim learning is not suggested, hence it is important to motivate students that the presented worked example is to build their knowledge base.

Here is our procedure to create an example-problem pair:

| Steps             | Examples                                                                 |
|-------------------|--------------------------------------------------------------------------|
| Step 1:           | Make the example or the problem.                                          |
| \(A\) bank sets a deposit rate of 5% per year. If after depositing his money for a year, Andi’s money now is Rp 10,500,000.00, find Andi’s initial deposit! \(A\) bank sets a deposit rate of 6.5% per year. If after depositing his money for a year, Andi’s money now is Rp 13,500,000.00, find Andi’s initial deposit! |
| Step 2:           | Solve the problem with the complete procedure and as clear as possible.  |
| Suppose Andi’s initial deposit is \(x\) in rupiah. Because the rate is 5% a year and Andi deposited his money for a year, the interest he got is \(5\% \times x = 5x/100\). Hence his money now in \(x\) is \(x + 5x/100 = 105x/100\). We get the equality \(105x/100 = 10,500,000\). Now we solve for \(x\). \(105x/100 = 10,500,000\) \(105x = 10,500,000 \times 100\) \(x = (10,500,000 \times 100) ÷ 105\) \(x = 10,000,000\) So, Andi’s initial deposit is Rp 10,000,000.00. | \(1\) A bank sets a deposit rate of 6.5% per year. If after depositing his money for a year, Andi’s money now is Rp 13,500,000.00, find Andi’s initial deposit! |
| Step 3a:          | For surface isomorphism, change the quantity of the problem (1). The teacher can also change the wording of the problem (2), or change the story while sticking in the same context (3).          |
| \((1)\) A chemist mixes \(x\) liter of liquid \(A\) and \(0.1x\) liter of liquid \(B\). If the mixture produced is 11 liter, find the amount of liquid \(A\)! \((2)\) If Andi’s age is a quarter of his father’s age and the sum of their ages is 50, find his age! |
| Step 3b:          | For deep isomorphism, check the equation in the solution. After that, make a new problem in a different context that will produce that equation. |
| Step 4:           | Formulize the example-problem pairs.                                     |
| \((1)\) Andi borrows some money from bank \(A\) with an interest rate of 6.5% per year. If Andi has to pay Rp 13,500,000.00 by the end of his loan period, how much money did he borrow from the bank? \((2)\) If Andi’s age is a quarter of his father’s age and the sum of their ages is 50, find his age! |
| \((3)\) If Andi has Rp 13,500,000.00 in a bank with a deposit rate of 6.5% per year, how much is his initial deposit? |
| \((3)\) Andi’s initial deposit is Rp 10,000,000.00. |
| \((3)\) Andi borrows some money from bank \(A\) with an interest rate of 6.5% per year. If Andi has to pay Rp 13,500,000.00 by the end of his loan period, how much money did he borrow from the bank? |
| \((3)\) Andi’s initial deposit is Rp 10,000,000.00. |
| \((3)\) Andi borrows some money from bank \(A\) with an interest rate of 6.5% per year. If Andi has to pay Rp 13,500,000.00 by the end of his loan period, how much money did he borrow from the bank? |
Following the steps above, here is the example-problem pair.

| Worked-Example                                                                 | Paired Problem Solving |
|--------------------------------------------------------------------------------|------------------------|
| A bank sets a deposit rate of 5% per year. If after depositing his money for a year, Andi’s money now is Rp 10,500,000.00, find Andi’s initial deposit! | A chemist mixes x liter of liquid A and 0.1x liter of liquid B. If the mixture produced is 11 liter, find the amount of liquid A! |

**Step 1: Listing all the information from the problem.**
The interest is 5% and Andi’s money now is Rp 10,500,000.00.

**Step 2: Deciding the variables.**
Suppose Andi’s initial deposit is \( x \).

**Step 3: Making the algebraic equation.**
\[ x + \frac{5x}{100} = 10,500,000 \]

**Step 4: Solve the equation**
\[ x + \frac{5x}{100} = 10,500,000 \]
\[ 100x/100 + 5x/100 = 10,500,000 \]
\[ 105x/100 = 10,500,000 \]
\[ 105x = 10,500,000 \times 100 \]
\[ 105x = 1,050,000,000 \]
\[ x = 1,050,000,000 \div 105 = 10,000,000 \]

**Step 5: Conclude the answer**
So, Andi’s initial deposit is Rp 10,000,000.00.

To implement the isomorphic problems into example-problem learning method in the classroom, we propose four stages: apperception, solving problems in example-problem worksheet (students are asked to study the solution step-by-step independently then students are asked to complete the missing steps in the paired problem solving), presenting the solution to the peers, solving problems without looking at the example, and drawing a conclusion after all pairs are studied.

3.1. Apperception
The apperception can be included in the worksheet or the teacher can also give it before giving the worksheet. It must be given in the form of problems only without any examples or solutions. By repeatedly using problems only in apperception, the students are used to remembering previous topics without relying on the examples. They are also forced to study the previous topics independently because if they do not study they can not answer the problems in apperception.

After the students are done with the problems, the teacher discusses the problems briefly. The focus of the discussion must be an important topic that forgotten by the majority of the students. This part is important because students with sufficient apperception knowledge can understand the example thoroughly and in a relatively short time, while the students whose does not have enough apperception knowledge usually takes more time to understand the example [30].

3.2. Solving Problems in Example-Problem Worksheet
The first core activity is solving the problems by using the knowledge gained by the examples provided. The example part of the example-problem pair must be designed so that students can understand how the problem is solved easier [29]. The instruction must be given as clear as possible so that the student can maximize the knowledge they gained from the example. If they do not understand the example, then it can not be used as prior knowledge for them. Toward that goal, the teacher must give an additional explanation if needed. With clear example, if students follow the steps of solution contained in the example sequentially, then understand the explanation at each step, they will understand the problem-solving model [30]. Instructing students to highlight an important part or step by themselves in the worksheet may also help.
After understanding the problem, students proceed to work on the problem. The students must be encouraged to only look at the example part if needed. By repeatedly doing this, the students’ analogical transfer ability is expected to be improved.

3.3. Presenting Solutions
After doing the example-problem pairs, the students will present their answer to the class. The teacher may choose the students at random so the students know that they have to prepare themselves in case they are chosen. The teacher either confirm the answer is correct or give feedback needed if the answer is incorrect.

3.4. Solving Problems without Looking at the Example
The last core activity is solving problems that do not have an example pair. In this activity, students are expected to use the prior knowledge they gained in previous activity to solve the problems. The teacher may give another isomorphic problems to solve. This activity is meant to assist students to automate their just acquired knowledge.

3.5. Conclusion
The teacher may guide students to draw conclusions about what they have gained during the learning process [30]. The teacher should lead the students to draw correct conclusions about the strategy of solving the problems they have just learned in order to make sure students deeply understand the knowledge. Students are expected to keep the knowledge in long-term memory so they can recall it when dealing similar problems.

4. Conclusion
In creating the example-problem pairs by using isomorphic problems, first, we have to know which isomorphism we want to use. When we make isomorphic problems in surface isomorphism, we can change the quantities, the wording, or the story while keeping the context same. If we want to use deep isomorphism, the pair must have a different context. In general, the example must be easy to understand, the quantities in the pair are not necessarily the same or different, the problem should have exactly the same solution procedure with the example, and the students must be encouraged to only look at the worked-example if needed.

In using the example-problem pairs, first, we need to make sure the students have the necessary prior knowledge from previous topics. After that, we give them the example-problem pairs. Students need to present the answer so they know the mistakes they may have. The students also need to work on problems without the examples to get used to using prior knowledge. Last, the teacher should ask students to conclude their learning results.

References
[1] Davidson J E and Sternberg R J 2003 The Psychology of Problem Solving ed J E Davidson and R J Sternberg (Cambridge: Cambridge University Press)
[2] OECD 2016 PISA 2015 Results (Volume I) (OECD Publishing)
[3] Mullis I V S, Martin M O, Foy P and Hooper M 2016 TIMSS 2015 International Results in Mathematics (Chestnut Hill, MA: IEA)
[4] Usman M, Abdul R and Ansari S A 2017 Analysis of the ability in mathematical problem-solving based on SOLO taxonomy and cognitive style World Trans. Eng. Technol. Educ. 15 68–73
[5] Wijaya A, Heuvel-panhuizen M Van Den, Doorman M and Robitzch A 2014 Difficulties in solving context-based PISA mathematics tasks : An analysis of students’ errors Math. Enthus. 11 555–84
[6] Surya E, Syahputra E, Yuniza Eviyanti C and Simbolon M 2017 Improving the Students’ Mathematical Problem Solving Ability by Applying Problem Based Learning Model in VII
Grade at SMPN 1 Banda Aceh Indonesia Int. J. Nov. Res. Educ. Learn. 4 138–44

[7] Prahani B K, Limatahu I, Yuanita L and Nur M 2016 Effectiveness of Physics Learning Material Through Guided Inquiry Model To Improve Student’s Problem Solving Skills Based on Multiple Representation Int. J. Educ. Res. 4 231–42

[8] Retnowati E, Ayres P, Sweller J, Retnowati E, Ayres P and Sweller J 2016 Journal of Educational Psychology Can Collaborative Learning Improve the Effectiveness of Worked Examples in Learning Mathematics? Can Collaborative Learning Improve the Effectiveness of Worked Examples in Learning Mathematics?

[9] Kirschner P A, Sweller J and Clark R E 2006 Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching Educ. Psychol. 41 75–86

[10] Van Gog T 2011 Effects of identical example-problem and problem-example pairs on learning Comput. Educ. 57 1775–9

[11] Kalyuga S, Chandler P, Tuovinen J and Sweller J 2001 When problem solving is superior to studying worked examples. J. Educ. Psychol. 93 579–88

[12] Sweller J and Cooper G A 1985 The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra Cogn. Instr. 2 59–89

[13] Mwangi W and Sweller J 1998 Learning to Solve Compare Word Problems: The Effect of Example Format and Generating Self-Explanations 16 173–99

[14] Bradshaw Z and Hazell A 2017 Developing problem-solving skills in mathematics: a lesson study Int. J. Lesson Learn. Stud. 6 32–44

[15] Polya G 1975 How to Solve It: A New Aspect of Mathematical Method (New Jersey: Princeton University Press)

[16] Hall G 2016 Mathematics Problem Solving Strategies

[17] Chan J, Paletz S B F and Schunn C D 2012 Analogical problem solving under uncertainty Mem. Cogn. 40 1352–65

[18] Gentner D 1983 Structure Mapping: A Theoretical Framework for Analogy Cogn. Sci. 7 155–70

[19] Cushen P J and Wiley J 2018 Both attentional control and the ability to make remote associations aid spontaneous analogical transfer Mem. Cogn. 46 1398–412

[20] Barnett S M and Ceci S J 2002 When and where do we apply what we learn? A taxonomy for far transfer Psychol. Bull. 128 612–37

[21] Gick M L and Holyoak K J 1980 Analogical problem solving Cogn. Psychol. 12 306–55

[22] Gick M L and Holyoak K J 1983 Schema induction and analogical transfer Cogn. Psychol. 15 1–38

[23] Reeves L and Weisberg R W 1994 The role of content and abstract information in analogical transfer. Psychol. Bull. 115 381–400

[24] van Gog T, Kester L and Paas F 2011 Effects of worked examples, example-problem, and problem-example pairs on novices’ learning Contemp. Educ. Psychol. 36 212–8

[25] Greer B and Harel G 2002 The role of isomorphisms in mathematical cognition J. Math. Behav. 17 5–24

[26] Reed S K 1999 Word problems: research and curriculum reform

[27] Mayer R E 1981 Frequency norms and structural analysis of algebra story problems into families, categories, and templates Instr. Sci. 10 135–75

[28] Reed S K, Ernst G W and Banerji R 1974 The role of analogy in transfer between similar problem states Cogn. Psychol. 6 436–50

[29] Retnowati E and Marissa 2018 Designing worked examples for learning tangent lines to circles J. Phys. Conf. Ser. 983

[30] Rohman H M H and Retnowati E 2018 How to teach geometry theorems using worked examples: A cognitive load theory perspective J. Phys. Conf. Ser. 1097