Metacognitive

by Ariyadi Wijaya

ME – 15

METACOGNITIVE PROMPT AS A MEANS TO IMPROVE STUDENTS' TASK COMPREHENSION

Ariyadi Wijaya[1]; Marja van den Heuvel-Panhuizen[2]; Michiel Doorman[2]
[1]Mathematics Education Department, Yogyakarta State University, Indonesia
* Corresponding email address: a.wijaya@staff.uny.ac.id
[2]Utrecht University, the Netherlands

Abstract

One of the most dominant errors made by (Indonesian) students when solving context-based PISA mathematics tasks is error in comprehending the task. This paper reports a study on improving students' comprehension of context-based tasks. A total of 299 eight graders from six junior high schools in the Province of Yogyakarta participated in this study. The study employed a field experiment with a pretest-posttest control-group design for which we used an intervention program comprising a set of context-based tasks which were implemented with metacognitive prompts. The result of the study shows a significant difference between the experimental group and the control group on the decrease in the total number of errors (χ^2 (1, n = 4127) = 4.149, p = .042). In comparison to their counterparts in the control group, the students in the experimental group had a better improvement regarding two aspects of task comprehension: understanding the instruction of the task and selecting relevant information.

Key words: context-based tasks; metacognitive prompts; task comprehension

INTRODUCTION

Several studies (Ananiadou & Claro, 2009; Partnership for 21st Century Skills [P21], 2002) have reported that modern society requires people to be able to apply their knowledge. This situation has led to educational practices that provide students with not only knowledge, but also skills they need for life and community (Griffin, Care, & McGraw, 2012). In mathematics education a great deal of attention has been attached to developing students' ability to apply mathematics. Mathematics curriculum should focus on "mathematics that will prepare students for continued study and for solving problems in a variety of school, home and work settings" (NCTM, 2000, p. 14–15). Students' ability to apply mathematics is also considered as an important goal of mathematics education in Indonesia. The new Curriculum 2013 mandates that education must be relevant to the needs of life and offers students opportunities to apply their knowledge in society (Kementerian Pendidikan dan Kebudayaan [the Ministry of Education and Culture], 2012). This mandate is in line with the goals of mathematics education mentioned in the former *School-based curriculum* (KTSP), i.e. to develop students' ability to: (1) solve problems that require the ability to understand a problem, design and complete a mathematical model to solve it, and interpret the solution; and (2) appreciate the purpose of mathematics in life (Pusat Kurikulum [The Regulation of the Minister of National Education, No. 22, Year 2006, about Standards of Content). Furthermore, Indonesia has regularly participation in PISA, which is a large scale assessment examining students' ability to apply mathematics.

Despite a strong attention to the application of mathematics in Indonesian curriculum, the PISA results show Indonesian students' low performance on context-based tasks which indicates students' low ability to apply mathematics. In the latest PISA 2014 for example, less than 1% of Indonesian students could solve mathematics problems that are situated in complex situation and require mathematical modeling and well-developed reasoning skills (OECD, 2013). To get a better insight into the low performance of Indonesian students on context-based tasks, Wijaya, Van den Heuvel-Panhuizen, Doorman, and Robitzsch (2014) analyzed students' difficulties when solving such tasks through an error analysis. They found that (Indonesian) students mostly have difficulties at the early stages of solving context-based tasks, i.e. comprehending a context-based task and transforming it into a mathematical problem. In relation to these difficulties, Wijaya, Van den Heuvel-Panhuizen, and Doorman (2015) revealed correspondences between students' errors in solving context-based tasks and the characteristics of context-based tasks in Indonesian textbooks. Wijaya, Van den Heuvel-Panhuizen, and Doorman (submitted) also found correspondences between students' errors and teachers' teaching practices. The teachers involved in Wijaya et al.'s study tend to use directive teaching in which they give direct instructions and help to students. Such teaching approach is the opposite of the recommendation of experts (e.g. Blum, 2011) that teaching context-based tasks should be conducted through a student-centered and investigative teaching approach in which students are actively involved and the teacher's role is consultative rather than directive.

The correspondences between students' errors in solving context-based tasks and the educational practices – i.e. the quality of textbook tasks and the teaching approach used by teachers – indicate possible ways to improve students' performance. One of the possible ways is developing appropriate teaching practice. This paper describes the use of metacognitive prompts in mathematics teaching-learning as an attempt to improve students' performance on context-based tasks. This paper limits the students' performance from the perspective of students' ability to comprehend a context-based task, which in this paper is called as 'task comprehension' . The research question that is addressed in this paper is " *what is the effect of metacognitive prompts on students' task comprehension?*"

METACOGNITIVE PROMPTS AND CONTEXT-BASED TASKS

With respect to teaching context-based tasks, several studies (Antonius et al., 2007; Blum, 2011) recommended teachers use consultative teaching in which they play a consultative role and give students opportunities to actively build new knowledge and to reflect on their learning process. A key aspect for consultative teaching is to keep a balance between teacher guidance and students' independence for which Antonius et al. and Blum recommended the use of metacognitive prompts. Metacognitive prompts help students to become more aware of the process and the aspect of solving mathematics problems.

Metacognitive prompts can be provided in the form of self-addressed questions, which means students are asked to question themselves while solving a problem. Self-addressed questions are important to help students regulate, verify, and reflect on the solving process (Kramarski et al., 2002; Montague, 2007). Kramarski et al. (2002) and Montague (2000; 2007; 2008) found that a question like *"What is the problem about?"* is helpful for students to understand a context-based task. Kramarski et al. (2002) also found that a self-addressed question which focuses on strategy, e.g. *"What strategies are appropriate to solve the problem?"*, can guide students learn identifying the procedures required to solve a context-based tasks. Lastly, a reflection question, e.g. *"Does my solution make sense?"*, is appropriate to stimulate students reflect on the reasonableness of their solution (Kramarski et al., 2002; Montague, 2007). Another kind of metacognitive prompts is giving verbal prompt or instruction to help students focus attention on particular aspects of solving process and assist themselves to carry out the process (Montague, 2007; Montague et al., 2000). For example, an instruction like "Underline the important information" (Montague, 2007; 2008) can be used to direct students to focus on identifying relevant information, which is an important aspect of comprehending a context-based task. Asking students to paraphrase a task is also an important prompt regarding

the comprehension stage. Karbalei and Amoli (2011) found that paraphrasing can improve students' problem comprehension.

RESEARCH METHOD

To answer the research question, we carried out a field experiment with a pretestposttest control-group design. In the experimental group, the teachers used an intervention program for their teaching, intended to offer students opportunity-to-learn to solve context-based tasks. In the control group the students followed ateaching program that was developed on the basis of the textbook that they regularly use.

In total, 311 eight graders ($M = 13.8$ years; $SD = 0.5$ year) from Junior High Schools in the Province of Yogyakarta participated in the study. These students were situated in two groups, i.e. experimental group (146 students) and control group (165 students). However, the data analysis was based on the 299 students ($M = 13.7$ years; $SD = 0.5$ year) who were present during both the pretest and the posttest. Of these students, 144 students were in the experimental group and 155 students in the control group.

The intervention program for the experimental group was metacognitive prompt embedded in a set of context-based tasks (see Figure 1). The metacognitive prompts were meant to point students to important aspects of the tasks and the solving process. A first metacognitive prompt was asking students to underline all the information included in a context-based task and to discuss the included information. For example, in the Internet task this prompt was given in the first assignment. As a second metacognitive prompt, students were asked to use their own words to explain the Internet task. This paraphrasing of a given problem was a second type of metacognitive prompt to help students to get a better understanding of what the problem is about. Finally, a third type of metacognitive prompt was to elicit self-questioning. For example, in the Internet task students were stimulated to ask themselves questions, such as "What strategy can we use to solve Doni's problem?".

Figure 1. Internet task

An internet provider Inter-NET offers two different programs. Program Smile charges customers 30.500 IDR as monthly fee and 40 IDR/1 Megabyte (MB). Program Shine charges customers 20.000 IDR as monthly fee and 52 IDR/1 MB. The registration fees including the price of modem for both programs are the same, namely 300.000 IDR. In January Doni subscribed to the program Shine. In May Doni used 550 MB of internet data. How much money did he pay in May?

a. *Underline all information given in the task and circle only the information we need to answer the question.*

b. *Reformulate the task with less words by leaving out unnecessary information.*

c. How much money did Doni pay in May?

Doni's internet usage is increasing. Now, he has a problem to decide whether it will be wise to change the internet program.

d. *What strategy can we use to solve Doni's problem?*

e. When Doni's internet usage is increasing, is it better for him to change the internet program? If so, when should he do it?

Error analysis

Students' task comprehension was seen from the perspective of comprehension error. For this purpose, an error analysis was performed for which an analysis framework developed by Wijaya et al. (2014) was used to code students' errors. The error analysis was done only on students' incorrect answers (in the pre- and post-tests). The coding was carried out by the first author. The interrater reliability of the coding was checked through an extra coding by a mathematics teacher who was not part of this study. The extra coding was done on the basis of 12% of the coded responses, which were randomly selected. With a Cohen's Kappa of .78, the agreement between the first author and the second coder was substantial (Landis & Koch, 1977).

RESULT AND DISCUSSION

In total, 1942 incorrect responses were found in the pretest (892 in the experimental group and 1050 in the control group) and 1705 incorrect responses were found in the posttest (744 in the experimental group and 961 in the control group). In accordance with our finding on the correctness of the students' answers the decrease in incorrect responses between the two groups was not significant $\chi^2 (1, n = 3647) = 1.934, p = .164$). However, it was the opposite for students' errors (see Table 1). There was a significant difference between the experimental group and the control group on the decrease in the total number of errors ($\chi^2 (1, n = 4127) = 4.149, p = .042$).

Table 1

The number of errors made by the students in the pretest and the posttest

Types of errors	Sub-types of errors	Group	Number of errors		Percent of change
			Pre-test	Post-test	
Comprehension	Errors in understanding instruction	Exp.	68	51	- 25%[a]
		Control	84	93	11%
	Errors in understanding a keyword	Exp.	22	36	64%
		Control	14	39	179%
	Errors in selecting information	Exp.	125	86	- 31%
		Control	125	127	2%
	Total	Exp.	215	173	- 20%
		Control	223	259	16%
Transformation	Procedural tendency	Exp.	7	15	114%
		Control	2	9	350%
	Taking too much account of context	Exp.	11	8	- 27%
		Control	20	10	- 50%
	Wrong mathematical procedure	Exp.	487	376	- 23%
		Control	582	442	- 24%
	Treating a graph as a picture	Exp.	68	59	- 13%
		Control	69	87	26%
	Total	Exp.	573	458	- 20%
		Control	673	548	- 19%
Mathematical processing		Exp.	195	165	- 15%
		Control	230	239	4%
Encoding		Exp.	32	33	3%
		Control	58	53	- 9%
Total		Exp.	1015	829	- 18%
		Control	1184	1099	- 7%

[a] A negative value means a decrease

This paper only focuses on the effect of the metacognitive prompts on students' task

comprehension; therefore the discussion only includes the comprehension errors. Table 1 shows a positive influence of the intervention program (i.e. the metacognitive prompts) on students' comprehension errors. In the experimental group the number of errors decreased by 20%, whereas in the control group the occurrence of these errors increased by 16%. Particularly, the finding that there the number of errors in selecting information errors decreased by 31% and the number of misunderstanding the instruction decreased by 25% provides evidence that the metacognitive prompts helped. This was also supported by the fact that in the posttest work of the students in the experimental group showed clear signs of underlining and circling information. This was, for example, the case in the Skateboard task in which students were asked to calculate the minimum and the maximum price for self-assembled skateboards (see Figure 2). This task provided a price list that included irrelevant information. A typical error when solving this task was that students included irrelevant information in their calculation. In the pretest this was done by 19 out of 72 students in the experimental group and by 21 out of 80 students in the control group. In the posttest this error decreased to 6 in the experimental group and to 12 in the control group.

Figure 2. A trace of circling relevant information in students' response

CONCLUSION AND SUGGESTION

A closer examination of students' errors showed a positive effect of metacognitive prompts on students' ability to comprehend context-based tasks. This finding, which is in agreement with other studies (Karbalei & Amoli, 2011), indicates the potential of the paraphrasing strategy to develop students' task comprehension. The improvement in students' task comprehension was also reflected in the progress students made in selecting relevant information. This result signifies the benefit of asking students to circle only the relevant information. This metacognitive prompt seems to be effective in guiding students to thoroughly look at the information provided in the task.

Comprehending a context-based task is the first of four main steps to solve context-based tasks (see Blum, 2011). If students cannot comprehend a context-based task – e.g. do not know what the task is about or do not know the information that is relevant to solving the task – then it will hinder students from correctly solving the task and getting the correct answer. It means comprehending a task is really crucial. Therefore, paying attention to improving students' task comprehension would be a crucial step to improve students' general performance on context-

based tasks. The results of the present study indicates the benefits of metacognitive prompts to improve students' performance. Furthermore, from the perspective of the new Indonesian Curriculum 2013, metacognitive prompt fits the scientific approach. The self-addressed question used in the present study is similar to the second phase of scientific approach, i.e. questioning. The prompt to underline and circle information is related to the observing phase of scientific approach. Therefore, we suggest teachers to consider and include metacognitive prompt in their teaching practice; it is not only to develop students' task comprehension, but also students' mathematics performance in general.

REFERENCES

Ananiadou, K., & Claro, M. (2009). 21st Century Skills and competencies for new millennium in OECD countries. *OECD Education Working Papers, No. 41*. OECD Publishing. httpx://dx.doi.org/10.1787/218525261154.

Antonius, S., Haines, C., Jensen, T. H., Niss, M., & Burkhardt, H. (2007). Classroom activities and the teacher. In W. Blum, P. L. Galbraith, H.-W. Henn & M. Niss (Eds.), *Modelling and Applications in Mathematics Education: The 14th ICMI Study* (pp. 295–308). New York: Springer.

Griffin, P., Care, E., & McGaw, B. (2012). The changing role of education and schools. In P. Griffin, B. McGraw & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 1–16). New York: Springer.

Karbalei, A., & Amoli, F. A. (2011). The effect of paraphrasing strategy training on the reading comprehension of college students at the undergraduate level. *Asian EFL Journal, 13*(3), 229–344.

Kementerian Pendidikan dan Kebudayaan. (2012). *Dokumen Kurikulum 2013* (The document of the Curriculum 2013). Jakarta: Author.

Kramarski, B., Mevarech, Z. R., & Arami, M. (2002). The effects of metacognitive instruction on solving mathematical authentic tasks. *Educational Studies in Mathematics, 49*(2), 225–250.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159–174.

Montague, M. (2007). Self-regulation and mathematics instruction. *Learning Disabilities Research and Practice, 22*(1), 75–83.

Montague, M. (2008). Self-regulation strategies to improve mathematical problem solving for students with learning disabilities. *Learning Disability Quarterly, 31*(1), 37–44.

Montague, M., Warger, C., & Morgan, T. H. (2000). Solve it! Strategy instruction to improve mathematical problem solving. *Learning Disabilities Research and Practices, 15*(2), 110–116.

National Council of Teachers of Mathematics. (2000). *Principles and standard for school mathematics*. Reston: Author.

OECD. (2013). *PISA 2012 Results: What students know and can do. Student performance in mathematics, reading and science*. Paris: Author.

Partnership for 21st Century Skills. (2002). *Learning for the 21st century. A report and mile guide for 21st century skills*. Tucson, AZ: Author.

Wijaya, A., Van den Heuvel-Panhuizen, M., Doorman, M., & Robitzsch, A. (2014). Difficulties in solving context-based PISA mathematics tasks: An analysis of students' errors. *The Mathematics Enthusiast, 11*(3), 555-584.

Wijaya, A., Van den Heuvel-Panhuizen, M., & Doorman, M. (2015). Opportunity-to-learn context-based tasks provided by mathematics textbooks. *Educational Studies in Mathematics, 89*(1), 41 – 65.

Wijaya, A., Van den Heuvel-Panhuizen, M., & Doorman, M. (submitted). Teachers' teaching practices and beliefs regarding context-based tasks and their relation with students' difficulties.

Metacognitive