

# Dynamic Exploration on Self-Explanation Prompts in Complex Tasks

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**Abstract:** This study explored the effects of the focus (inference or inference followed by integration) and assistance level (less vs. more) in self-explanation (“SE”) prompts on learning outcomes measured by procedural- and conceptual knowledge and whether these improvements persisted over time. A total of 129 South Korean students who enrolled in economic instruction were randomly assigned to one of four conditions: IF-LA, IT-LA, IF-MA and IT-MA. The results revealed that there was an interaction effect of the focus and level of assistance of SE prompts on delayed conceptual knowledge. Prompts that focused on inference followed by integration resulted in significantly higher immediate conceptual knowledge test scores than prompts that focused only on inference. These findings indicated that SE prompt must be designed considering these two factors according to target knowledge.

## Introduction

Being equipped with a highly systemized set of knowledge, (i.e. Economics), is in other words to be able to solve various problems in different situations in an equally systemized manner, (Feltovich, Prietula, & Ericsson, 2006), and this is only possible when the core concepts of such problem-solving process is understood completely (Van Gog, Paas, & Van Merriënboer, 2004).

SE is the generation of explanations for oneself to understand the principles of the learning material and each problem-solving steps (Chi, Leeuw, Chiu, & LaVancher, 1994), and self-explanation prompts are best suited to stimulate learning outcomes within certain domains. In their notable study, Berthold, Eysink, and Renkl (2009) developed assisting SE prompts that induce a focused processing of conceptual aspects of mathematical probability. While prompts were irrespective of procedural aspects, they could foster procedural knowledge. The assisting SE prompts allows enough cognitive capacity to concentrate not only on the prompts-induced conceptual aspects but also on the problem-solving process. While it was expected for them to induce conceptual knowledge, self-explanation prompts seem to hinder the acquisition of procedural knowledge. Several scholars (Berthold, Röder, Knörzer, Kessler, & Renkl, 2011) argued that, under complex learning circumstances, prompts that attract learner’s attention to a certain aspect would impede the deeper processing of other important aspects. Therefore, meticulously designed prompts are needed for facilitating both procedural and conceptual knowledge to solve a complex task. This study explores the ways to design the focus and level of assistance of SE prompts in economics for enhanced learning outcomes (procedural and conceptual knowledge) and persistency of such improvements.

SE promotes learning in two primary ways (Rittle-Johnson & Loehr, 2017). First, SE encourages inference generation on a material that they do not fully understand. Nokes, Hausmann, VanLehn, and Gershman (2011) argued that gap-filling prompts are particularly efficient for the development of problem-solving schemas. Second, SE empowers learners to integrate pieces of new information and to combine them with prior knowledge. When studying texts with problem-solving examples, learners’ SEs often link solution steps with prior knowledge or information in the text (Atkinson, Renkl, & Merrill, 2003). In this study, we hypothesized that *integration-based prompts* (i.e., generating inference followed by integration) would enhance performance for complex tasks. Since learners were not only required to generate inferences from simple tasks, but also needed to integrate their inferences with prior knowledge to complete more complex tasks (Morrison, Bol, Ross, & Watson, 2015; Van Merriënboer & Kirschner, 2012). Chi et al. (1994) also suggested that the prompts were designed to reflect a range of difficulties (e.g., category 2 and 3 questions).

Although prompting SE has been recognized as a way to improve learning process, sometimes, even when prompted, learners are unable to generate reasonable explanations as they do not know how to engage in SE. Providing a structured SE format is an instructional technique for improving the quality of SE (Rittle-Johnson & Loehr, 2017). Yet, previous studies on various SE-assisting procedures have shown mixed results (, since an incomplete SE bears the risk of disturbing learners’ constructive activities. Thus, it is important to identify the appropriate level of prompting assistance that elicits SE and foster meaningful learning. As an alternative, Berthold et al. (2009) suggested that assisting SE prompts, like fill-in-the-blank followed by open-ended questions, should be provided when assistance is necessary. However, learners should build their own schemas rather than relying on external resources to learn how to organize complex learning process (Van Merriënboer &

Kirschner, 2012). This study attempted to see whether providing learners with keywords with open questions followed by open-ended question prompts, or *less assisting SE prompts*, affected learning outcomes.

As discussed above, previous research has demonstrated the effect of the focus and assistance level of SE prompts independently. To date, little research has been done about the effect that the combination of the focus and assistance level of SE prompts have on learning outcomes for complex tasks. The main research questions addressed: 1) what are the effects of the focus and assistance level of SE prompts on procedural knowledge? (immediate and delayed test), and 2) what are the effects of the focus and assistance level of SE prompts on conceptual knowledge? (immediate and delayed test)

## Method

### Participants and research design

This study was conducted in a high school in Suwon, South Korea. The participants were 129 tenth grade students (female: 55%) who had already learned about the concept of exchange rates through their regular curriculum. A 2×2 experimental study was conducted using the factors of (a) the focus of SE prompts – inference (“IF”) vs. inference-generating followed by integration (“IT”); (b) the assistance level of SE prompts - less assistance (“LA”) or an open question with keywords followed by open questions vs. more assistance (“MA”) or fill-in-the-blank questions followed by an open question. Participants were randomly assigned to one of four conditions: LA-IF (n = 29), LA-IT (n = 26), MA-IF (n = 36), and MA-IT (n = 38).

### SE prompts embedded in learning materials

The research team and economic teachers with 3 to 5 years of experience each developed experimental materials based on previous research (Van Gog et al., 2004). All learning materials were paper-based and provided process-oriented worked examples because such examples showed learners the correct way to perform a complex task while explaining why it was done that way (Van Merriënboer & Kirschner, 2012). Three examples of gradually increasing complexity that showed the participants how to determine the impact of exchange rate fluctuations on the economy, were used: (Task 1) ‘Predict changes in international currency exchanges from an analysis of domestic economy.’ (Task 2) ‘Analyze the impact of exchange rate fluctuations on an export company.’ (Task 3) ‘Analyze and evaluate an import company’s financial losses from exchange rate fluctuations.’ The solution step was omitted from example to execute the fading strategy. The prompts were given in place of the solution step and the learners were required to answer one prompt for each step of the example (Fig. 1). The “IF” prompt corresponded to the one in the study of Conati and VanLehn (2000), and was focused on generating inferences to fill the gaps (e.g., ‘The answer is correct because...’). The “IT” prompt was adapted from another study (Chi et al., 1994), and was designed to facilitate an integration between prior knowledge and new information (e.g., ‘What is different from the previous task?’ or ‘How does it relate to what you have already seen?’). The “LA” prompt was again an open-question but with keywords for Task1 and 2 and more open-ended question for Task 3. The “MA” prompt was same as the one used by Berthold et al. (2009) and consisted of a fill-in-the-blank question for Task 1 and Task 2, and an open-ended question for Task 3.

|                     | increasing complexity |                            |                            |                      |
|---------------------|-----------------------|----------------------------|----------------------------|----------------------|
|                     | Task 1                | Task 2                     | Task 3                     |                      |
| Focus               | Inference(IF)         | Generate inferencing       | Generate inferencing       | Generate inferencing |
|                     | Integration(IT)       | Generate inferencing       | Generate inferencing       | Integration          |
| Level of assistance | Less (LA)             | Open question with keyword | Open question with keyword | Open-ended question  |
|                     | More (MA)             | Fill-in-the-blank          | Fill-in-the-blank          | Open-ended question  |

Figure 1. Description of learning materials.

### Measurement

The pretest examined the participants’ knowledge on the concept of exchange rates through questions. The posttests assessed both procedural and conceptual knowledge and conducted immediately after the learning session and on the following week. The immediate test included 9 items for assessing procedural knowledge and 3 items for conceptual knowledge, while delayed test included 3 and 5 items, respectively. Questions for procedural knowledge included, “Calculate the change in export value of \$30,000 when the exchange rate rises from 1,000 KRW to 1,200 KRW,” and for conceptual knowledge, questions such as “Look at trends in exchange rates and write reasons why certain trends would be favorable to exporters or importers” were asked.

### Procedures

The experiment was composed of two sessions. The first session included a 7 minute-long pretest, the learning phase, and the immediate posttest. During the learning phase, the participants studied 3 complex tasks with

process-oriented worked examples for 10 minutes each. The participants then completed their respective SE activities for each prompt for 10 minutes each. The first posttest lasted 10 minutes, while the second session took place a week later for 15 minutes.

## Results

To ensure homogeneity among four experimental groups with regard to prior knowledge, a one-way ANOVA test was conducted ( $F(3, 125)=1.626, p=.187$ ). The group means, standard deviations were analyzed (Table. 1).

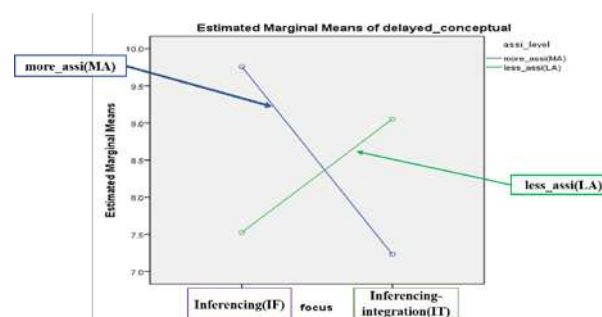
**Table 1: Means and standard deviations of learning outcomes across groups**

| Aspect    |            | IF-LA |      | IT-LA |      | IF-MA |      | IT-MA |      |
|-----------|------------|-------|------|-------|------|-------|------|-------|------|
|           |            | M     | SD   | M     | SD   | M     | SD   | M     | SD   |
| Immediate | procedural | 4.50  | 2.15 | 5.11  | 2.39 | 5.31  | 2.48 | 5.46  | 1.77 |
|           | conceptual | 4.64  | 3.21 | 6.61  | 2.99 | 5.24  | 3.42 | 6.42  | 3.24 |
| delayed   | procedural | 3.08  | 2.43 | 4.11  | 2.02 | 4.14  | 2.03 | 4.38  | 2.11 |
|           | conceptual | 7.53  | 4.16 | 9.05  | 3.30 | 9.76  | 3.33 | 7.23  | 2.93 |

Two-way MANOVA was conducted to examine the effects of focus and assistance level of self-explanation prompts on learning outcomes. Box's M test for homogeneity of covariance matrices (Box's  $M=20.482, F=.642, p=.934$ ) and Levene's F tests of equality of variance matrices were not significant for learning outcomes ( $p$  ranged from .051 to .929). Utilizing Wilks' Lambda criteria, the interaction effect was significant (Wilks'  $\Lambda=.917, F(4,122)=2.777, p=.030, \eta_p^2=.083$ ) and the main effect of the SE prompts' focus was significant (Wilks'  $\Lambda=.894, F(4,122)=3.628, p=.008, \eta_p^2=.106$ ). However, the main effect of SE prompts' level of assistance was not significant (Wilks'  $\Lambda=.963, F(4,122)=1.182, p=.322, \eta_p^2=.037$ ).

### Effects on Procedural knowledge

Follow-up ANOVAs, concerning immediate and delayed procedural knowledge, the main effect of the SE prompts' focus was not significant ( $F(1, 125) = .903, p = .344, \eta_p^2=.007, F(1,125)=2.703, p=.103, \eta_p^2=.021$ , respectively). There was also no interaction between level of assistance and focus of SE prompts ( $F(1,125)=.326, p=.569, \eta_p^2=.003, F(1,125)=1.009, p=.317, \eta_p^2=.008$ , respectively).



**Figure 2.** Interaction between focus and assistance level of SE prompts on delayed conceptual knowledge.

### Effects on conceptual knowledge

Follow-up ANOVAs, for immediate conceptual knowledge, the main effect of the SE prompts' focus was significant ( $F(1,125) = 7.60, p=.007, \eta_p^2=.057$ ), implying that IT prompts condition obtained significantly higher scores on immediate test than IF prompts condition (mean difference = 1.57,  $ES(d)=.49$ ). Yet, there was no interaction effect ( $F(1,125)=.472, p=.493, \eta_p^2=.004$ ). For delayed conceptual knowledge, there were no main effect of the SE prompts' focus ( $F(1,125)=.644, p=.424, \eta_p^2=.005$ ), but an interaction between the focus and level of assistance of SE prompts ( $F(1,125)=10.516, p=.002, \eta_p^2=.078$ ), as shown in Fig 2. The simple main effects showed that focus and assistance level of SE prompts had a significant effect on delayed conceptual knowledge in the IF prompts group ( $F(1,125)= 5.484, p=.04$ ), meaning that MA prompts group had higher score than LA prompts group (mean difference=2.23,  $ES(d)=.61$ ). On the other hand, focus of SE prompts had a significant effects on delayed conceptual knowledge among LA prompts group ( $F(1,125)= 8.828, p<.001$ ), implying that IT prompts group had significantly higher score than IF prompts group (mean difference=2.53,  $ES(d)=.69$ ).

## Discussion

The results reveal that the focus and assistance level of SE prompts affect learning outcomes depending on the target knowledge, and three conclusions can be drawn from these results. (a) There was an interaction effect between focus and assistance level of the SE prompts on delayed conceptual knowledge (See, Fig 2). Or, in using inference-based prompts, a learner would establish a strong problem-solving schema and correct domain knowledge through generating inference with the help of more assisting self-explanation prompts in the initial learning phase. In this case, despite increasing task complexity, a learner would have no need to compare or integrate his/her understanding. In contrast, using the integration prompts that are less assisting in early stages of learning, makes a learner to build a relatively weak problem-solving schema through the inference generation. Therefore, as learning phase progresses, a learner finds it necessary to integrate what is understood and revise any incorrect knowledge. These results suggest that the focus of self-explanation prompts could be designed in various ways depending on the level of assistance of the self-explanation prompt. (b) Contrary to the hypothesis, the different types of prompts showed no significant difference in their influence on procedural knowledge, and the result is also contradictory to the aforementioned findings of Berthold et al. (2009). This could be due to lack of learners' prior knowledge, as the learners only had a very basic concept of exchange rate. In other words, the learner could not spare his/her attention to the acquisition of other types of knowledge including procedural knowledge, because the assisting prompts have drawn attention to a particular type of knowledge (Berthold et al., 2011).

This research calls for further studies to address the following two limitations and to conduct more experiments, in order to broaden the universality of the implications presented so far. (a) This study excluded an experimental condition of providing only structured SE prompts while some study proved their efficacy for learning performance higher than open-question SE prompts (e.g., Gadgil, Nokes-Malach, & Chi, 2012). Thus, future research would need to include this condition. (b) The measures for learning consisted of a short list of questions. Further research would need to scrutinize procedural and conceptual knowledge with more extensive set of tests to take a closer look at the impact of self-explanation prompts on learning outcomes.

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