Leave Some Space to Think: Can Less Guidance Bring More Product?

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Abstract: The purpose of the study was to develop an optimal form of support during the problem-solving phase in productive failure for the learners to benefit most from their failing experience. Learners' Representation and Solution Methods ("RSM") and cognitive load were analyzed accordingly. The results indicate that there are statistically significant differences in learners' RSM diversities based on the types of metacognitive prompt provided to each group, while the effect of the different types of metacognitive prompt on RSM structuredness and cognitive load are not significant.

Keywords: Productive failure, metacognitive prompt, representation and solution methods

Introduction

Productive failure is an instructional strategy that encourages learners to directly confront novel, complex problems through non-content-related support followed by instruction phase afterwards (Kapur, 2016). Through this delayed-instruction strategy, learners can be trained to think of their own solutions in a self-determined way while using and developing cognitive structures to solve novel problems. The complex problem is an instructional device to activate prior knowledge (either informal or intuitive), perceive knowledge gap, and generate RSM to the problems. The problem-solving process augments learners' data source and empowers the learners to transfer skills even if they fail to solve problems. The efficacy of the complex problem can be explained by *solution generation effect* which argues that the learners would perform better when they generate more RSMs (Kapur, 2012).

Much effort has been made for the learners to turn their failing experiences to be 'glorious'. Often, a learner may go through a failure from lacking domain knowledge, not from a condition in which they find it difficult even to start. To compensate for the lacking domain knowledge and to facilitate RSM generation, this study focused on providing metacognitive prompts during the problem-solving phase. The metacognition involves both knowledge and regulation of cognition and compensates for the lack of relevant domain-specific knowledge. Hence, in the absence of domain-specific and structural knowledge, the metacognition becomes critical for solving ill-structured problems (Wineburg, 1998) as they require both types of knowledge (Ge & Land, 2004). The experiment by Roll et al. (2012) showed that the learners outperformed in invention activity when they were provided with metacognitive prompts.

Meanwhile, the amount of support should also be considered because offering too much support may obstruct achieving productive failure, that is, to encourage learners to come up with their own solution. Guiding the whole process of problem-solving on evaluating and refining their solutions may improve RSM structuredness, but too much content in the worksheet (or material) would rather increase cognitive load. Concomitantly, drawing learners back repeatedly into situations that they had already skipped because they lacked the relevant knowledge can frustrate and exhaust them.

Therefore, it is necessary to devise an optimized prompt that contributes to an affordable failing experience. Such a prompt may allow a space to generate more RSMs by providing learners with less work than a fully-supporting prompt. Reviewing learners' RSMs during the problem-solving phase can be both time- and effort-consuming, and can ultimately become meaningless because the instruction phase provides a chance for learners to revise and compare their RSMs with a concrete lesson. Optimized prompt can, however, prevent cognitive overload from the difficulty and complexity of problems.

This study attempted to answer two research questions: (1) *In what ways do the different types of metacognitive prompt affect learners' RSMs in terms of diversity ("RSMD") and structuredness ("RSMS")?* (2) *In what ways do the different types of metacognitive prompt affect learners' cognitive load?*

Method

The research questions were tested in a quasi-experimental study on 106 undergraduate students who are majoring in mechatronics and enrolled in Intro to Mechatronics course in a university in Seoul, Korea. The participants were asked to solve two complex problems with peers and provided with prompts that offered no support, optimized support, or full support. Results based on three measurements were collected throughout the session; RSMD (Cronbach's $\alpha = .82$), RSMS (Cronbach's $\alpha = .86$), and cognitive load (Cronbach's $\alpha = .87$).

Results

The dependent variables for research question 1 were RSMD and RSMS. A MANCOVA test was conducted with different types of metacognitive prompt as the between-subjects factor, and the pretest score as the covariate. There was a significant multivariate effect of metacognitive prompt on participants' RMSD and RSMS scores ($F(2,102) = 2.589$, $p = .038$, $\eta_p^2 = .048$). However, one of the univariate effects of metacognitive prompt was not significant: RSMD ($F(2,102) = 4.954$, $p = .009$, $\eta_p^2 = .089$) and RSMS ($F(2,102) = 1.583$, $p = .210$, $\eta_p^2 = .030$). The result indicates that both the optimized support (mean difference = 1.077, $p = .048$) and no support group (mean difference = 1.333, $p = .014$) scored significantly higher on RSMD than the fully supported group. The difference between the RSMD scores of the optimized support group and no support group was not significant.

The dependent variable for research question 2 was the cognitive load. An ANCOVA test was conducted with different types of metacognitive prompt as the between-subjects factor, and the pretest score as the covariate. The difference among groups was not significant ($F(2,102) = 2.045$, $p = .135$, $\eta_p^2 = .039$).

Discussion

This study investigated the effect of different types of metacognitive prompt in association with the diversity and structuredness of learners' RSMs and cognitive loads. The MANCOVA test revealed that the optimized support and, surprisingly, the no support groups generated more RSMs than the full support group. The no support and optimized support groups could have benefitted from having their datasets regulated, leading to the *solution generation effect* (Kapur, 2012). This result is linked to the concept of productive failure, which is to problematize learners without giving guidance. Nonetheless, the findings propose that among different forms of support during the problem-solving phase, non-guided failures allow more opportunity to generate ideas or RSMs than the guided failures.

This study focused on the effects of changes in the problem-solving phase, thus, RSMS were measured to examine whether the fully supported group would generate more structured RSMs than the others. The results show that the differences among the groups' RSMS scores were not significant. This result can be explained by the nature of the metacognitive prompt that does not provide cognitive support. It is consistent with the findings of Kapur (2011), who found that having fewer failures during the problem-solving phase was not beneficial to learners' learning outcomes.

It was expected that the optimized support would reduce extraneous load hence have more room for the germane load. However, this study found that there was no statistically significant difference among the experimental groups' cognitive loads. This can be attributed to the fact that the learners did not consider the prompt to be a guidance nor they reported cognitive load based on the complexity of the problems instead of their own internal states. Measuring cognitive load after failed complex problem-solving experience may not make sense, as it would result in relatively high cognitive load. This study showed that reducing learners' cognitive loads through prompts is ineffective, therefore suggests future research to consider how to design productive failure environments that can reduce cognitive load and produce a productive failing experience.

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