The Effects of Index Construction in a Case Library

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Abstract: Generating indices in learning from cases is a constructive learning activity that improves understanding of lessons in the cases. A broadened problem space with meaningful indices acts as prior experiences of practitioners in the fields when they try to solve a real-life problem. The effectively generated indices facilitate the process of retrieve and reuse the cases to solve a problem. Therefore, prompting index construction activities is essential instructional support, but which types of prompts better facilitate the constructive index generation activity remain unclear. The current study aimed to explore the effects of index construction activities on problem-solving skills. This research employed a quasi-experimental design with a control group and two treatment groups of different types of prompts for index constructions. The results showed that learners who were prompted to generate indices outperformed the learners in the control group in constructing argumentations, specifically explanation-based indices were beneficial in making counterargument and rebuttals, and difference-based indices in making rebuttals. The findings suggest appropriate indices based on both exploration of each case and comparisons among cases can improve argumentation as they facilitate the process of retaining, retrieving, and reusing cases.

Keywords: Case library, Index construction, Problem-solving, Prompt

INTRODUCTION

One of the fundamental pedagogical approaches of constructivism is that learning should be situated in solving authentic problems, not in direct instruction from instructors (Hmelo-Silver, Duncan & Chinn, 2007; Jonassen, 2011). Learners in such learning environments learn to solve problems on their own, and thus, take the lead in their learning (i.e., student-centered learning environment; Piirto, 2011). Learners construct their knowledge for themselves while they solve the given problems. Learners are no longer passively transferred information from instructors. A lot of responsibilities for their learning are required in student-centered problem-solving. This transfer of the initiative in learning from teachers to learners has been proved as advantageous through various studies in problem-based learning (Dochy, Segers, Van den Bossche & Gijbels, 2003; Hmelo-Silver, 2004). The more learners are responsible for their learning, the more benefits learners can earn.

There is no doubt, in such a student-centered learning environment, that learners need enough guidance not to be lost in their journey of learning. If not guided enough, learners are often cognitively over-loaded or distracted to irrelevant aspects of tasks, resulting in poor knowledge construction (Kirschner, Sweller, & Clark, 2006; Mayer, 2009). Therefore, adequate level and amount of scaffolding are necessary to fulfill the cognitive and metacognitive requirements for learning to solve problems (Ge & Land, 2004). For example, Ge and Land (2003) reported the benefits of question prompts and peer interactions in PBL. According to their study, both question prompts to facilitate the ill-structured problem-solving process and peer interactions for a collaborative problem-solving process are useful scaffolding strategies in that they induce learners to process important information and build group ideas interactively.

However, scaffoldings such as question prompts or peer interaction do not have additional benefits in facilitating analogical reasoning and similarity assessment, which are also essential skills that learners should be supported to solve an ill-structured problem (Tawfik, 2017). Given this gap, Jonassen and Tawfik (2013) employed case libraries in learning to solve decision-making problem as a scaffolding strategy. Case libraries provide learners with several cases delivering practitioners' experiences of success or failure as indexed stories. As expert practitioners use case-based strategies when they solve real-life problems, cases can act as prior experiences of expert practitioners. They help learners employ case-based reasoning and solve the problems based on the lessons from the cases (Jonassen, 2011).

Provided with cases, learners can better argue for their solution (Jonassen & Hernandez-Serrano, 2002; Tawfki & Jonassen, 2013). This beneficial effect of case libraries on argumentation depends on how appropriately and sufficiently they create internal indices for cases and reuse the lessons from the cases. As narratives of cases have lessons or perspectives to be learned, learners are exposed to multiple views from individual cases. Learners can expand the problem space when they retain lessons from various cases (Choi & Lee, 2008) with indices easily retrievable. With cases adequately indexed, learners may consider multiple perspectives while developing an argumentation. Various lessons from indexed narratives can be sources and evidence of a sound argumentation which often include initial claims, counterarguments, and rebuttals (Jonassen & Tawfik, 2013). As the quality of argumentation for the solution often determine how well learners solve ill-structured problems, providing cases is an effective way of scaffolding problem-solving (Jonassen, 2011).

Giving cases only, however, does not ensure successful construction of knowledge in the learning domain. In a case library learning environment (CLE), learners are expected to draw lessons from individual cases, make internal indices, and construct a problem schema to solve a given problem well. However, this process of learning cases can be very challenging to novices. Cases contain context-specific experiences and lessons. Sweller (2011) argue that biologically secondary knowledge, also known as domain-specific knowledge, needs instructional support to be acquired. In other words, learners hardly discover cultural knowledge without appropriate and explicit teaching and learning (Geary, 2008), which entails a cognitive process of selecting, organizing, and integrating new information. However, presenting cases of practitioners' experiences as a form of a narrative does not seem to be enough to encourage learners to process the information. Without appropriate instructional intervention, learners are likely to construct indices unsuccessfully, in other words, their indices would be based on irrelevant or unhelpful information for solving problems. Therefore, other forms of scaffolding to promote index construction are necessary to maximize the effects of case libraries on argumentation skill improvement.

We assume, in this case, that prompts embedded in each case would be an effective form of instructional support. Though over-scaffolded examples of ill-structured problems may hinder learners' self-directed, constructive learning and result in reproducing teacher's thinking (i.e., instructional explanation) (Jonassen, 2011), we still believe that prompts for index construction can maximize their generative thinking (i.e., self-explanation) such as inferring information that are not explicitly stated, comparing and contrasting cases, and repairing their existing knowledge. These generative activities are recently referred to as constructive ones rather than active ones according to the ICAP framework that Chi and Wylie (2014) proposed. If prompts given to learners only encourage them to replicate the information verbatim, their learning activities would be active or passive. On the other hand, if the prompts induce them to infer, compare or contrast the information, or repair the knowledge, learners will go through a constructive cognitive process. Information obtained from constructive activities not only enhance the understanding of examples more but also remains more retrievable than the presented one does (Hausmann & VanLehn, 2010).

Studies addressing the effects of prompting self-explanation when learning from examples are mostly those of procedural domains such as science and mathematics (Chi & Wylie, 2014). However, prompting self-explanation is still vital instructional support in non-algorithmic domains when learners are to understand the underlying principles and how they are reflected in the process of making solution though non-algorithmically (Schworm & Renkl, 2007). Meanwhile, the research of Tawfik (2017) investigated the effects of prompts in CLE in the domain of business. The prompts used in Tawfik's research function as facilitators of the problem-solving process as learners represent problems, identify problem space, select solution, justify solution and evaluate the proposed resolutions with the questions (retain prompts), or compare the individual cases based on specific points stated in questions (retrieval/reuse prompt). Both types of prompts, however, do not encourage learners to generate indices for individual cases, of which quality would positively influence learning from cases. They only indirectly influence internal index construction when learners select and justify the solution based on the cases or the comparisons of the cases. As learners, novice practitioners, are expected to learn the contents as well as the causal reasoning process when they solve ill-structured problems (Tawfik, Gill, Hogan, York & Keene, 2017), prompts for understanding contents of cases as well as ones for problem-solving process need to be investigated. How much constructive activities induced by prompts when learners study the vicarious experiences, cases in the form of narratives, are advantageous to learning to solve problems, and which types of prompts for index generation are effective for facilitating the constructive activities remains unclear. Therefore, the goal of this research is to investigate the effects of different types of prompts for index construction in CLE.

Given this gap, this study compares three different condition groups; failure-based cases without prompts and failure-based cases with embedded prompts for individual cases, comparing cases. The first prompt type is based on the failure-driven memory and reflects an explanation-based indexing method in CBR, while the second is based on failure-driven memory and reflects a difference-based indexing method in CBR. The explanation-based indexing allows a reasoner to explain why a solution does not work or a particular perspective is particularly crucial in the given context (Kolodner, 1993). This method encourages learners to put indices on individual cases in terms of each distinctive feature. On the other hand, the difference-based indexing allows learners to distinguish cases from one another, resulting in higher predictability at retrieve and reuse phases (Kolodner, 1993). This method encourages learners to put indices based on the common or different aspects. To examine the effects of prompts on learners' ill-structured problem-solving skills (i.e., argumentation skills in this context), the following research questions were posited:

To what extent do index construction activities improve learners' performance on a decision-making argumentation task differ if they are provided with prompts for explanation-based indices, difference-based indices, or without prompts in conjunction with failure-based cases?

1) To what extent do initial claim scores in learning task differ among three condition groups?
2) To what extent do counterclaim scores in learning task differ among three condition groups?
3) To what extent do rebuttal scores in learning task differ among three condition groups?

METHODS

Context and Participants

This study was conducted in a career planning course at a large university in South Korea. All freshmen were required to take this course in their first semester to fulfill their general education requirements. This course required students to explore their characteristics, interests, and occupational view; and investigate different careers, learn strategies for rational decision-making and develop a career plan. The course employed a flipped learning model. Every week, two video lectures of 20 minutes long each were presented, and 3-hour classroom activities including lectures and discussion were offered to students.

A total of 111 first-year students from a wide variety of majors were enrolled in this course across three sections. The instructor informed students a week before the problem-solving phase that an experiment was being conducted as part of a learning activity and all the text-based data from problem-solving activities would be collected for the experiment. All students agreed to participate in the experiment.

Design

The purpose of this study was to investigate how argumentation scores differed among the groups provided with the different types of prompts in conjunction with a case library. All the cases were designed as failure-based ones since Tawfik and Jonassen (2013) reported that learners benefit more from failure-based cases in terms of making counterarguments than success-based cases. Tawfik and Jonassen argued that learners might have more chance of generating indices from cases of failure because learners can be exposed to the mental discomfort that characters of the narratives faced and the following process of making explanations for the unexpected result, which usually offers alternative perspectives.

For the experiment, a quasi-experimental design with three treatment groups was used: 38 students in the condition of cases without prompts (a control group), 37 students in the condition of prompts for individual cases (a group of explanation-based indexing method, EBI), and 36 students in the condition of comparing cases (a group of difference-based indexing method, DBI) in conjunction with failure-based case library. Among these groups, an ANOVA revealed that there were no significant differences in argumentation scores on the pre-test, $F(2, 108) = .644$, $p = .527$. This indicates that students in three different groups were equivalent in their argumentation skills.

Materials

An hour and a half were assigned to the case-based learning phase in all conditions, which we found not enough time for learners to read very long, text-only narrative. Given this limitation, instead of long narratives which are often used in CLE, we constructed each story as a low-density text to reduce reading time. To build low-density text, a question-and-answer format was adopted. Using a low-density text can reduce learning time, without compromising learning outcomes (Ross & Morrison, 1989). The main problem to solve is also designed as low-density texts as shown in figure 1. It asks learners to think of the most desirable decision that the character, Huijae, would make about her future career and develop an argumentation for the decision as if they gave advice to her.

Different types of prompts for cases shown in figure 2 are developed based on the explanation-based and difference-based indexing methods. The former includes three questions in a set, which ask learners to explore the failures and the expectation of failure, infer what explanation of failures would be and repair the existing knowledge. As four cases were provided in CLE, four sets of prompts were respectively designed. The latter consists of four questions in a set, which directly require learners to compare two cases in terms of the personalities, which are the learning contents, and the failures each character faced. Learners are also prompted to think about the lessons and things to be taken into account when people like the mentors make decisions about their careers. Two sets of comparison prompts were developed for four cases. The variables to be compared among the cases were identified and determined by an instructor, author III, who has taught this course for years. All the materials including problems used in pre-test and learning phase, cases, and prompts were presented in Korean.

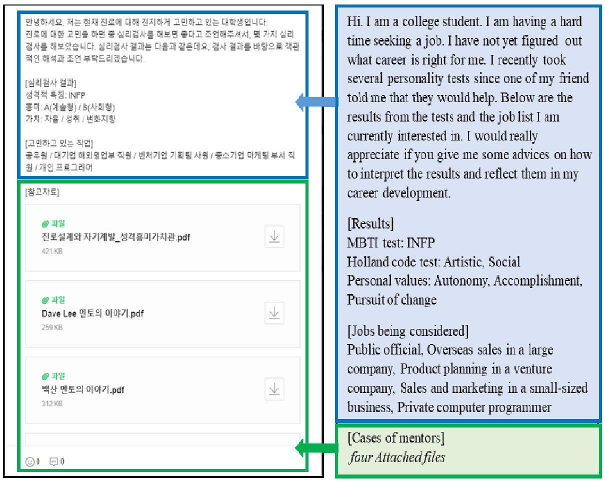

Figure 1. A main problem (Huijae's dilemma) and cases as attached files.

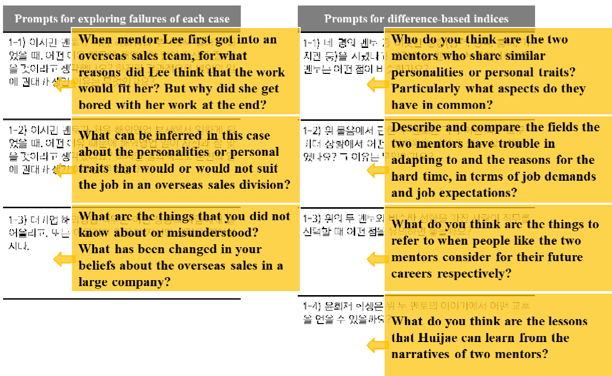

Figure 2. Examples of prompts for index construction activities.

Procedure

During the experiment, the instructor used BAND, a mobile and web-based social network service, which provides private online bulletin boards and discussion boards that people invited only can have access. Each group of 2 to 3 students was given a separate, private discussion board where they can have a chat, engage in a group discussion, and solve the given ill-structured problem.

One week before the problem-solving activity, a pretest on argumentation skills was taken. A similar decision-making problem to the main problem was presented. The problem was designed as identical as possible to the learning task regarding its structure (e.g., certain multiple perspectives to be considered), but the surface features such as characters, contextual details were different. Students were required to make an argument individually. They were prompted to include three different components (initial argument, counterargument, rebuttal) in their argumentation (Tawfik and Jonassen, 2013; Tawfik, 2017). Learners should first give their initial claim as to which career path best suit the character. They are encouraged to give as many pieces of evidence as possible. Then, they present an alternative solution with convincing evidence against the initial solution. The counterargument may be derived from other perspectives and positions. Lastly, learners may challenge the counterclaim in terms of its validity or weaker influences, or synthesize the initial and counter arguments (Tawfik and Jonassen, 2013).

During the problem-solving activity, the instructor posted the main problem to solve in the BAND. Four related cases, which students can access through hyperlinks embedded in the main problem, were also provided. Students were encouraged to read the main problem and the associated cases for 30 minutes. Meanwhile, three different groups across three sections were offered different types of prompts attached to each case. Students in group 2 and 3 were required to answer the given prompts while students in group 1 received no prompts. Students who were not provided with prompts were instead allowed to write down ideas that occur to them spontaneously. The learning time for case studies is kept constant among the groups.

After reading the main problem and cases individually, students were encouraged to have a group discussion through text-based online chatting environment to resolve the main problem. After 30 minutes of group discussion, students were required to develop their argumentation for the solution individually and post it on BAND for another 30 minutes. Learners developed their argumentation in the same format used in the pre-test.

Coding

We used the holistic argumentation scoring rubric for pre-test, adapted from Jonassen and Cho (2011) (See Table 1). Two researchers, author I, and II met after independently coding 20 argumentation essays to assure two coders share the agreements about the rubric. The inter-rater reliability was moderate (Cohen's kappa = .79). Inter-rater reliability reached 100% after coding the remaining essays and negotiating the scores. The scoring rubric for learning tasks was adapted from Tawfik and Jonassen (2013), of which components consists of initial argument, counterargument, rebuttal and holistic scores calculated by aggregating the three scores. (see Table 2). Inter-rater reliability was also moderate (Cohen's kappa = .74) after coding 20 essays. The remaining essays were coded, and the differences in assigned scores between two raters were all resolved through discussion.

Table 1. Argumentation scoring rubric for pretest (Adapted, Jonassen & Cho, 2011)

Level	**Description**
0. Response to topic	Essay does not provide a clear claim.
1. Undeveloped opinion	Essay states a clear claim but no reason is given to support the claim, or the reason given is unrelated to the claim
2. Minimally developed	Essay provides a clear claim and reasons supporting the claim, but the reasons are not well explained or elaborated
3. Partially developed	Essay provides clear claim and substantial reasons that are well explained and elaborated, but no counterclaim is addressed.
4. Well developed	Essay provides a clear claim and counterclaim and rebuts the counterclaim, but some reasons supporting the claim or rebutting the counterclaim are not well explained or elaborated.
5. Fully developed	Essay provides a clear claim and a plausible counterclaim, and they are supported by substantial reasons that are well explained and elaborated. The essay effectively rebuts the counterclaim with substantial reasons and/or proposes a valid alternative solution that addresses counterclaim concerns.

Table 2. Argumentation scoring rubric for a learning task (Adapted, Tawfik & Jonassen, 2013)

Com-ponents / Points	**Initial argument**	**Counter Claim**	**Rebuttal**
0 points	No initial argument or claims are inconsistent	No clear counterargument stated or claims are inconsistent	No clear rebuttal stated or claims are inconsistent
1 points	Argument is clear and supported by a single reason	Counterargument is clear and supported by a single reason	Rebuttal is clear and supported by a single reason
2 points	Argument is clear and supported by multiple reasons that are not specifically explained and elaborated	Counterargument is clear and supported by multiple reasons that are not specifically explained and elaborated	Rebuttal is clear and supported by multiple reasons that are not specifically explained and elaborated
3 points	Argument is clear and supported by multiple reasons that are partially explained and elaborated	Counterargument is clear and supported by multiple reasons that are partially explained and elaborated	Rebuttal is clear and supported by multiple reasons that are partially explained and elaborated
4 points	Argument is clear and supported by multiple reasons that are specifically explained and elaborated	Counterargument is clear and supported by multiple reasons that are specifically explained and elaborated	Rebuttal is clear and supported by multiple reasons that are specifically explained and elaborated

RESULT

The current study attempted to examine the effects of different types of prompts for index construction in conjunction with failure-based case library on the initial, counterclaim, and rebuttal scores. An ordinal logistic regression was adopted because the dependent variables, the argumentation scores, were the ordinal data.

An ordered logistic regression was conducted for the initial scores. The test of parallel regression assumption was tested before the main analyses to confirm the statistic assumption. It yields x^2 (6)=.698 (p=.995), upholding the proportional odds assumptions for the model. The main analysis followed; for the initial scores, the ordinal logistic regression did not found significant differences (x^2 (2)=.649,p=.723) among the control group (M = 3.34, SD = .85), EBI group (M = 3.16, SD = 1.17), and DBI group (M = 3.19, SD = .86).

For the second dependent variable, counterargument scores, an ordered logistic regression was also employed. The assumption of parallel lines was turned out to be met [x^2 (6)=10.297 (p=.113)]. The main analysis found statistically significant differences (x^2 (2)=8.852,p=.012 between the control group (M = 1.42, SD = 1.08) and EBI group (M = 2.00, SD = .97; Log Odds = 1.325, p = .003, Effect Size = .54). No significant differences were found between the DBI group and either the control group or EBI group.

An ordered logistic regression was conducted again for the rebuttal scores. The parallel regression assumption was not violated [x^2 (6)=7.148 (p=.307)].As in the analysis of counterargument scores, the ordinal logistic regression found a significant difference between the control group (M = 1.71, SD = .98) and EBI group (M = 2.19, SD = 1.13; Log Odds = .96, p = .029, Effect Size = .49). Plus, there were also significant differences (x^2 (2)=8.464,p=.015) between the control group (M = 1.71, SD = .98) and DBI group (M = 2.28, SD = .85, Log Odds = 1.21, p = .007, Effect Size = .58).

In terms of overall argumentation scores, which is calculated by adding up the other three scores, an ANOVA was conducted with overall holistic scores (0-12). However, there were no significant differences [F (2, 108) = 1.979, p = .143] among the control group (M = 6.47, SD = 2.01), EBI group (M = 7.35, SD = 1.126), and DBI group (M = 2.28, SD = .849).

CONCLUSION

Researchers have proved that CLE is an effective learning environment to scaffold ill-structured problem-solving process (Tawfik & Jonassen, 2013; Tawfik, 2017). The scaffolds such as question prompts suggested in Tawfik's research (2017) can help learners to build problem space better and solve the problems, specifically in terms of alternative perspectives. To build on the research addressing the scaffolding in CLE, the current research has investigated the effects of prompts for index construction. This study employed two types of prompts for index construction: (1) prompts for explanation-based index construction, and (2) prompts for difference-based index construction. The results of the current study suggest that providing prompts when learners study individual cases has positive effects on argumentation skills improvements.

Learners in the two treatment groups did not seem to gain benefits from index construction activities when they made their initial stance. The initial claim scores of three different groups were not statistically different. This result resembles the Tawfik (2017)'s findings, which report that problem-solving prompts does not improve initial argument skills. Though it would be inappropriate to compare Tawfik's and the current research since the types and timing (either when studying cases or solving problems) of prompts were different, it is still inferred that further instructional support besides the provision of cases may not have enhanced the skills in constructing the initial argument. Given that the average scores of all the groups were over 3 points out of 4, it can be assumed that learners are in general good at presenting a solution that they believe is best.

On the other hands, learners who participated in explanation-based index constructions outperformed the control group in making counterarguments and rebuttals. We assume that prompts for explanation-based index construction may give learners more opportunities to learn lessons associated with multiple and failure-related perspectives from which alternative solution is derived. While answering the prompts included in individual cases, learners may generate indices based on the circumstances that bring about failure, and possible explanations for the unexpected failure. With the indices of the vicarious failing experience, learners can acquire a problem-related script which contains multiple competing perspectives (Tawfik & Kolodner, 2016). When learners are explicitly prompted to explore the failure, infer the possible explanation, and revisit their existing knowledge, their problem-related script will deviate from flat one and thus be broadened (Schank, 1999). Then their script will become more like the one in the character's memory. The more failure-related indices are put into learner's memory, the more similar their scripts become to one of the experienced practitioners, and the broader their problem space gets. With more circumstances taken into consideration, learners can better argue for alternative perspectives and better weigh the options to resolve the complicated situation or synthesize the possibilities to support the initial claims.

Learners provided with prompts for difference-based index construction also outperformed the control group in developing rebuttals. We believe that once learners are prompted to explore the failure, they are likely to generate more indices which extend their problem space, no matter which type of activities, either examining the individual case or comparing the cases, were facilitated. Learners may have more chance to extend their scripts when they try to figure out the commonalities and differences in regard to the circumstances of failures (Kolodner, 1993). When learners construct difference-based indices, they may distinguish the situational facts that cause certain results from other facts that bring about different results. Therefore, we can assume that learners can think of more ways to rebut the opposing arguments based on the situational differences. For this reason, it was surprising that no evidence was found that learners in the difference-based indexing group made better quality of counterarguments. It was the unexpected result because comparing cases require a process of identifying multiple perspectives in each case and figuring out which variables are related to the alternative perspectives.

There may be two possible explanations for this result. First, learners may have difficulties in identifying multiple perspectives, contrasting them with those of other cases, and figuring out the distinguishing factors all at the same time. However, this explanation has a limitation to generalize the result because there is still statistical evidence that learners benefit from the activities when they construct rebuttals when compared to the control group. Second, the sample size of the condition groups was not big enough to draw significant implication from the experiment. Though the ordered logistic regression for counterargument scores between the control group (M = 1.42, SD = 1.08) and the group of difference-based indices (M = 1.75, SD = .73) found no statistically significant difference (Log Odds = .814, p = .063), we anticipate that if an experiment with a more substantial number of participants is conducted, the differences caused by the treatment will become noticeable.

No evidence was found to tell which types of prompt design are desirable for scaffolding learning from cases. Both explanation-based indexing and difference-based indexing once prompted, would be helpful for the reasoners to retrieve and reuse the cases. In either way, learners are encouraged to search for situational variables that cause failure and generate indices so that they can retrieve the cases when they encounter similar problematic situations. Learners, once prompted, can better acquire an extended problem-related script from the vicarious experiences of failure, which can act as prior experiences on which practitioners rely when they encounter a new problem to solve.

Overall, our finding is parallel to the results of the research in the domains of well-structured problem-solving (Renkl, 2014). Opportunities to self-explain the concepts and principles underlying the examples enhance learner's engagement in processing the given materials and understanding of the learning contents. Students in the prompted condition outperformed the students in no prompts group in argumentation task because they have constructed internal indices while they answer the prompts attached to each case. The more they build meaningful indices, the better they retain the lessons, and the more predictable are the indices which they retrieve and reuse when solving the problems.

The current research, however, has limitations. First, the learning sessions of problem-solving were only three-week long. This period is not enough to see the educational value of CLE, the constructivist approach, as most learners are not accustomed to this type of instruction. Second, the sample size was not big enough, and the learning domain was limited. To generalize finding of this research to the other contexts, we need to investigate the effectiveness of the prompts in FBC with a large number of students in various fields of education.

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