Generation of Fill-in-the-Blank Questions from Concept Map and Preliminary Comparison between Multiple-Choice Task and Kit-Build Task

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(Received 6 June 2018 and accepted in revised form 7 December 2018)

Abstract In previous research, we proposed a framework for a kit-build concept map (KB map), in which a learner is provided a set of components with which to build a concept map. In that framework, the learner’s constructed map can be diagnosed automatically. The task of building a concept map out of provided components is a promising exercise for strengthening and assessing a learner’s comprehension of a learned topic. In general, the multiple-choice task of fill-in-the-blank (FIB) questions can also be used to strengthen and assess a learner’s comprehension, and the answers can be automatically evaluated. In this paper, we discuss our process for designing a set of FIB questions that can be generated from a concept map. Then, we compare the KB map task with the FIB multiple choice task. Both tasks can be generated from the same concept map: that is, from the same content. We compare the two tasks, using three science lessons for fifth graders in two classes. One class uses the KB map and the other uses the FIB questions. In this experiment, the KB task evaluated the learners’ comprehension more adequately than did the FIB question task, and the students in the KB class performed at a higher level than did the students in the FIB class.

Keywords: kit-build concept map task, fill-in-the-blank multiple choice task, comprehension strengthening, comprehension assessment

1. Introduction

A concept map is a diagram that depicts relationships between nodes expressing a topic(1). This diagram is often used as a tool to structurally represent an idea or a type of knowledge in various situations. In education, concept maps allow students to express their understanding of a targeted learning topic(2). There are many reports on the learning effects of using concept maps. However, concept maps built by students using their own words are very difficult for teachers to quickly evaluate. Therefore, although the concept map is useful as a learning activity and for summative assessment, evaluating it does not result in real-time feedback.

In a kit-build concept map (KB map), all of the components, that is, the nodes and links, are provided to students, who are then required to build a concept map to express their understanding of a lecture(3, 4). Therefore, the kit-build task for a concept map is a promising exercise for strengthening and assessing learners’ comprehension of an already learned topic. The components are generated by deconstructing a map built by the teacher who made the lecture. A student’s map can be compared easily with the teacher’s map because they rely on the same components. Therefore, the KB map framework enable the automatic evaluation of a concept map. We have implemented the KB map framework, practicing it in several elementary schools. The results suggest there are noticeable learning effects to using a KB map(5–7).

To investigate the value of the concept map kit-building task, we compare it with the multiple-choice task involved in fill-in-the-blank (FIB) questions. The multiple-choice task of FIB questions is also used to strengthen and assess learners’ comprehension, and the answers can be automatically evaluated. Both tasks can be generated from the same series of propositions: that is, from the same content. Thus, comparing the two should suffice for investigating the value of the KB map task. KB mapping and doing FIB questions are both categorized as learning tasks that rely on recall and paraphrasing. In recall and paraphrasing, a memory is usually reconstructed, and that reconstruction results in a learning effect(8, 9). In the present research, we try to find the difference between the KB map task and the FIB question task in terms of learning effects and comprehension assessment.

We generated a set of FIB questions from a concept map and conducted an experiment in which fifth grade students in two classes received three science lessons. One class used the KB map (KB class) and the other class used the FIB questions (FIB class). Individual stu-
students in both classes used tablets to build their KB maps and answer the FIB questions. The result was that the KB task evaluated the learners’ comprehension more adequately than the FIB question task, and the KB class showed a higher level of performance after the test than the FIB class did.

In Section 2, we will discuss how we designed the set of FIB questions. In Section 3, we explain how we implemented the authoring tool for the concept map and how we generated the FIB questions from the concept map. In Section 4, we report on the experimental uses of KB maps and FIB questions we compare their learning effects.

2. The Relationship between a Series of FIB Questions and a Concept Map

A semantic unit in a concept map is a combination of two nodes that represent two concepts, respectively, and one link that represents the relationship between the two concepts. The link has a link word or phrase, which specifies the relationship. The combination of the two nodes and one relationship represents a proposition. In other words, a concept map expresses a series of propositions. Both the semantic network and the RDF expression have adopted the same notational system and are able to represent semantics basically. In this paper, a concept map is regarded as a set of propositions composed of two concepts and one relationship.

For example, in an elementary school science lesson on the “Movement of the Sun,” a teacher’s map might look like Figure 1. This teacher’s map was used in a previous paper. It is composed of four propositions: (1) the “sun” “rises in” the “eastern sky,” (2) the “sun” “passes through” the “southern sky,” (3) the “sun” “sits in” the “western sky,” and (4) the “sun” “doesn’t pass through” the “northern sky.” These four propositions are connected by “sun” and form a series of propositions. Here, a colored rectangle expresses a node and a phrase, composed of one or a few words in that rectangle, expresses the label of the node. We call that phrase a “node label.” A phrase in a white rectangle between two nodes expresses a label for the link. We call that phrase a “link label.” “Western sky” and “Sun” are node labels, and “Sets in” is a link label.

When a teacher inputs the four sentences and specifies the three parts (one or a few words) that correspond to the two nodes and one relationship in each sentence, the four sentences become the four propositions. Because the propositions are connected in a series with each other, they generate a concept map. This procedure “authors” a concept map from a set of sentences. When a series of propositions is generated, FIB questions can also be generated by specifying a blank in each proposition. For example, when all link words are specified as blanks in the above propositions, four FIB questions can be generated from the content. This procedure authors FIB questions from the same content as the concept map.

From the viewpoint of assessment characteristics, a set of FIB questions have a similar ability as a concept map. Therefore, we built KB maps and answered FIB questions using the same content to compare their learning effects. The procedure of authoring the KB map and the FIB questions is shown in Figure 2. In this example, a teacher writes a summary about the “movement of the sun” as a learning topic (step-1). Each sentence in the summary is required to form a proposition. Then, the
teacher must specify two concepts (as node labels) and a relationship (as a link label) for each sentence. In specifying those components, a proposition is made from each sentence. Thus, a set of propositions have been generated from the summary (step-2). From the set of propositions, a concept map for the learning topic is generated (step A-1). This map is the teacher’s map. If the propositions are not connected to each other, the teacher needs to modify the sentences or the specification of nodes or links. Deconstructing the teacher’s map results in a set of components to be provided to students (step A-2). To make the FIB questions, the teacher needs to specify the place for the blank in each sentence. The place should correspond to a node label or a link label (step B). Consequently, both the KB map and the FIB questions derive from the same proposition set. Both can be used to perform automatic assessments at the proposition level.

3. System

Figure 3 shows the answering interface of FIB questions. In the answering interface, several sentences with blanks are shown on the left side, and the set of choices are given in the right column. By drag and drop manipulation, a choice is placed in the blank in a sentence.

Figure 4 shows an example of a user’s answer interface with a KB map. By using the components provided on the left side of the interface, a learner builds a concept map using drag and drop manipulation. In both interfaces, all the words to be used to compose the answers are provided for the learners. The user’s answers are shown in the analyzer for the KB map(5). The link marked (A1) in Figure 4 shows a wrongly composed proposition, which is visualized with a red link, as shown. In the KB map, a wrongly composed proposition is interpreted as an incorrectly connected link. This mistake is called an “excessive link.” The missing, correct proposition is visualized by a blue link, marked (A2). We call the link a “lacking link.” When practicing with a KB map, both the excessive and the lacking links offer feedback(6,7).

4. Comparing a KB Map Exercise and a FIB Questions Exercise through Practical Use

4.1 Implementation of Exercises

Two classes of elementary school fifth graders participated in our study. The same teacher taught them over the course of three class times. The subject was science and the topic was “plant ecology.” In the last 10 minutes of each class, the teacher conducted an exercise to strengthen and confirm the students’ understanding of the lecture. One class, with 37 students, used the KB map exercise, and we call this class the “KB class.” The other class, also with 37 students, used the FIB question exercise, and we call this class the “FIB class.” In the KB map exercise, students were told to build a concept map composed of 10 propositions from the provided components (there were nine nodes and ten links). In the FIB question exercise, the students had to answer 10 FIB questions by selecting from multiple choices. The map and the questions were generated from the same teacher’s map. The teacher’s map corresponded to the
lectures. The teacher’s map was confirmed by another science teacher at the same elementary school. The FIB questions were generated by the teacher specifying a blank in each of the propositions. Therefore, the number of FIB questions was the same as the number of propositions. The teacher judged the difficulty of the questions to be appropriate for checking the learners’ comprehension.

In this study, the KB map exercise and the FIB question exercise were carried out three times, respectively, in each class: that is, in the KB class and the FIB class. The average score for the KB map exercise was 79.3 (SD=24.4) and for the FIB question exercise was 100 (SD=0.0). In the KB class, after the exercise, the teacher found several incorrect propositions in the class and gave feedback about those propositions. In the FIB class, there were no incorrect answers, so the teacher explained the importance of the propositions to the class.

4.2 Comparison of Learning Effects

After the exercises, the teacher conducted a post-test assessment that requested the students to answer four description questions about the learned topics. The questions are shown in Figure 5. The post-test assessment was marked by the teacher on the basis of the lectures. The answers to the questions in the post-test assessment are implied in the propositions, but the answers are not the propositions themselves. Therefore, the questions require the students to understand the meaning of the propositions. Specifically, the post-test assessment presents a problem that requires an explanation that uses multiple propositions.

To confirm the general level of science understanding for the two groups, we used scores from a general science test, which was conducted as part of the curriculum irrespective of this study. The general science test was provided by an exercise book used at the elementary school. Its contents derived from what was being taught to the whole fifth grade at that elementary school until the June of the sixth grade year. There were 46 problems in that test, and there were a selection formula and a description formula section. The implementation time was three weeks before this experiment. The alternative means used to show that there was no difference between the classes’ levels of content comprehension included: (1) no difference in the General Test and (2) a correlation between the General test and the post-test assessment. Although these means do not directly guarantee that there is no difference in the degree of prior understanding of the content, they are considered useful as suggestions. Because the two groups’ general test scores were almost same (there was no significant difference), as shown in Table 1, we assumed the two groups were equivalent in their science learning.

Table 1 shows the results of the post-test assessment. There was a significant difference between the scores of the KB class and the FIB class ($p=1.17E-13$), and the effect size was large ($d=0.71$). There were statistically significant correlations between the general test scores and the post-test scores in both groups as shown in Table 1 ($r=.63$ in FIB class, and $r=.59$ in KB class). This correlation suggests that the scores of the post-test assessment were reliable. Based on these results, we concluded that the KB map exercise had a better learning effect than the FIB question exercise.

4.3 Considerations

The results suggest that the KB map exercise had a...
better learning effect than the FIB question exercise, as the post-test score for the KB map class was significantly higher than the post-test score of the FIB class. Regarding comprehension diagnosis, no mistakes were found in the FIB class while they were found in the KB map class's results. The post-test scores suggest the learners’ understanding was incomplete; thus, the KB map diagnosis better captured the learners’ understanding of the targeted topics. However, the FIB questions were in a format that did not allow duplicate answers.

As to why the KB map task performed better, we considered the difference in the teacher’s feedback. It is impossible to exclude the possibility that there was a difference in the feedback content for each class from the teacher. On the other hand, in the FIB questions, learners had to think about the individual propositions in order to solve the problem. In the KB map, the learners needed to think about both individual propositions and the connections between the propositions requiring the learners to understand the propositions more deeply. Rather than thinking about individual propositions, the thinking about the connections between propositions, that is, the thinking about the information structure, led to a deep understanding.

5. Conclusion and Remarks

To investigate the value of the KB map task, we compared it with the multiple-choice task of FIB questions (the FIB question task). Both tasks were generated from the same concept map. We compared the two tasks using three science lessons for fifth graders in two classes. One class used the KB map, and the other used FIB questions. The results suggested that the KB task evaluated learner’s comprehension more adequately than the FIB question task, and the KB class performed better than the FIB class. Because this case study covers one topic, this experiment is preliminary. In future work, it will be necessary to conduct a larger sized experiment with multiple topics to confirm the generality of this result.

Another limitation to this study was that the teacher decided the answer choices, and difficulty was not controlled in this research. Therefore, it will be necessary in future research to discuss the kind of difficulty for which the KB map task is superior to the FIB question task.

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