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Effects of Online Scaffolded Student Question-Generation on Science Learning

Fu-Yun YU[a]*, Ting Jung CHIU[a], Han Chang TSAI[a], Chun-Ping WU[b] & Hui-Ling WU[a]
[a]*Institute of Education, National Cheng Kung University, Taiwan*
[b]*Department of Educational Technology, TamKang University, Taiwan*
*fuyun.ncku@gmail.com

Abstract: In this paper, the effects of scaffolded student question-generation (immediate and delayed) on students' performance in academic achievement and question-generation were examined. A total of 78 fifth-graders from four classes participated in the study for 13 weeks. An online question generation system was adopted to assist the learning process. A quasi-experimental research design was adopted. Results of ANCOVA found no statistically significant differences among different treatment groups in neither of the observed variables. Explanations for the unexpected results and suggestions for classroom implementations and future studies are provided.

Keywords: student question-generation, scaffolds, online learning activities, science learning

1. Introduction

Constructivists emphasize the notion that knowledge cannot be given to learners; instead, learning is most likely to occur in contexts where individuals are allowed to reflect and build their knowledge based on learning experiences [1]. Student-generated questions in essence reflect the ideas of constructivism. Based on their understanding of the learning materials, learners are given opportunities to highlight the contents they deem important, relevant and interesting [2], and transfer the information in the form of questions and answers. As a result, the student-generated questions approach to learning encourages students to reflect on what they learn and what it means in terms of their past learning experiences, current and future learning [3].

Despite the generally positive effects supporting the student-generated questions strategy [4], researchers found that a considerable proportion of students do not experience question-generation during their formal schooling [5-7]. Moreover, more than half solicited students viewed the student-generated questions as difficult or very difficult [8]. Thus, how to better support students to be adept and feeling equipped at generating questions will be a topic of importance.

Questioning guided by a set of question stems developed by King (1990) was found to promote peer interaction and learning in cooperative groups by enhancing the levels of posed questions and elaborated responses [9]. In light of this, and that existing studies comparing the effects of supporting strategies is limited, the study aimed to examine the effects of scaffolded student question-generation on student learning. Furthermore, according to Ertmer and Simons (2006), providing metacognitive support too early may interfere with student learning by adding difficulty to the task [10]. Some researchers further suggested metacognitive scaffolds to be introduced later in the process [11]. However, this presumption still lacks solid experimental studies for empirical confirmation. As such, the effects of delayed scaffolded student question-generation on student learning were also examined. Finally, in addition to the outcome variable of most concern to teachers (i.e., academic achievement), if and how would the scaffolds affect the task at hand (generating questions) was examined in the study.

To sum up, this study attempted to answer the following two questions:

1. How does scaffolded student question-generation (immediate and delayed scaffolds), as compared to no scaffolds, influence students' academic achievement in science?
2. How does scaffolded student question-generation (immediate and delayed scaffolds), as compared to no scaffolds, influence student's abilities in generating questions?

2. Methods

a. Participants, Learning Context and Experimental Procedures

To ensure enough group size, four 5th grade classes (N=78) of one elementary school in urban Taiwan were invited to participate. To minimize the scheduling and administrative problems that might be evoked by randomly assigning students to different groups, intact classes were used and randomly assigned to one of three experimental conditions except one class (which were randomly assigned to different treatment groups).

The online student question generation activity, implemented on *Question Authoring & Reasoning Knowledge System* (QuARKS), was introduced as supporting students' regular science learning. As science at the same grade level was taught by the same teacher at the participating school, instructional contents covered in each week were kept identical. Also, students in this participating school started taking computer classes since they were in 3th grade, and thus possessed fundamental skills of computer operations.

This study lasted for 13 weeks. As a routine, students of each treatment group head to a computer lab during regularly scheduled 40-minute morning study sessions one time per week to engage in this activity. Except for the first two sessions allocated for training and pre-treatment assessment, three sessions for the midterm, post-treatment assessment and final exam, respectively, students worked individually to generate short-answer questions in accordance with covered instructional topics for eight weeks. A training session was arranged at the beginning of the study to help students become familiar with good question-generation practices and the adopted computer system. Feedback to student performance in question-generation was done by the participating teacher by intentionally selecting three pieces of students' work as exemplary of good question-generation practice each week.

b. Different Treatment Groups

Three treatment conditions were set up. In Treatment A (no scaffold), no guides were provided for students' reference to support question-generation. In Treatment B (immediate scaffold), a set of guides were provided at the very beginning of their question-generation activity. In Treatment C (delayed scaffold), no scaffolds were provided until the group generated questions for two weeks.

Guides which were included in this study and provided to Treatments B and C were based on the question stems developed by King (1990) and Tung (2005) [9, 12]. Three science teachers from the participating school were invited to assess its relative appropriateness and usefulness for the subject matter (science) and participants (elementary schoolers). As a result of the expert validity assessment, fourteen question stems were included (e.g., can you write in your own words…? explain why…what was the main idea…? can you provide an example of what you mean…? how is…related to…that we studied earlier? how are …and…similar? what is the difference between…and…? can you group by characteristics such as…? what conclusions can you draw about…? how does…affect…?, etc.). In addition to question stems as scaffolds to students assigned to scaffolded question-generation groups (Treatment groups B and C), examples on using each of the question stems (based on science contents from the prior semester) were also provided and made online accessible to students assigned to scaffolded groups (see Figure 1 as an example). Students who were given scaffolds were requested to generate questions based on these prompts.

Import Stem	Generic Question-Stems	Sample Questions
Import this stem	What do you think might occur if ..... ?	What do you think might occur if a mammal was developed outside of its mother's body? What dangers would there be for the baby's survival?
Import this stem	What information do we already have about..... ? How does it apply to .... ?	What information do we already have about reptiles versus mammals? How do these differences apply to body temperature?
Import this stem	Are there any differences between. ... and.. .. ?	Are there any differences between learned and instinctive behavior ? Explain.
Import this stem	.... appears to be a problem because .... What are some possible solutions?	The untimely death of a mother appears to be a problem because of her role as nurturer ad teacher. What are some possible solutions for the baby's survival if she should die prematurely.
Import this stem	The author(s) states that "................." Explain why this statement is true or false.	The author(s) states that 'Mammals are the only animals that have hair or fur." Explain why this statement is true or false.
Import this stem	Compare. ... .and/with ....in regards to.. .... Explain your answer.	Compare incisors and canines with premolars and molars in regards to eating. Explain your answer.
Import this stem	What do you think causes···?	What do you think causes the shrinking of glaciers in the Arctic Circle?
Import this stem	How does ··· effect ···?	How does elevation affect temperature?
Import this stem	What is the meaning of ···?	What is the meaning of photosynthesis?
Import this stem	How are ··· and ···different?	How are assimilation and accommodation different?
Import this stem	Why is ··· important?	Why is conserving water important?
Import this stem	Explain how···	Explain how can we conserve energy?
Close		

Figure 1 Scaffolded student question-generation (question stems with samples questions)

c. *Measures*

Students' performance in science was measured by the average scores of mid-term and final exams, which were centrally administered at the participating school. Difficulty index for the majority of test items for the mid-term was between .71 and .91 and.52 and .79 for the final exam with Cronbach α □all reached the level of .90.

For measuring students' performance in generating questions, each question students generated at the last question-generation activity (8^{th} activity) were analyzed, scored and summed up against a defined scheme. Mainly, each question was graded along four dimensions: fluency, elaboration, originality and cognitive level. *Fluency* (0-3) assesses the correctness of spelling, clarity of sentence, the logic, and relevancy of the constructed question. *Elaboration* (0-2) gauges the interconnectedness between current covered topic/unit and prior topics/units and examples not from covered materials. *Originality* (0-2) taps on the uniqueness of the question as compared to their peers (including demonstrating innovative ideas and embedding new materials for graphical display or expression of covered content). *Cognitive Level* (0-3) evaluates the cognitive levels demanded of responders: *fact*, *comprehension* or *integration*. *Comprehension* indicates that students used their own words to define or describe learned content whereas *fact* stressed the verbatim nature of questions from the learned materials. *Integration* evidences a link has been built across topics/units and explanation has been provided to build connections. To ensure the reliability of this scoring procedure, the analysis work was done collectively by one of the author and a science teacher. Any inconsistencies between the raters were discussed and resolved.

3. Results

Descriptive statistics on student performance in science achievement and question-generation is listed in Table 1. Data on students' performance in academic achievement were analyzed using analysis of covariance (ANCOVA) with students' scores in science in the prior semester as covariate. The assumption of homogeneity of regression was satisfied, F (2, 72) = 1.76, p>.05, before proceed. Results from ANVOVA revealed that there were no statistically significant differences among three groups, F (2, 74) = 1.78, p > .05. This indicated that scaffolds (immediate or delayed), as compared to no scaffolds, did not affect students' academic achievement differently.

Data on students' performance in question-generation were analyzed using ANCOVA with students' scores at the 1st question-generation activity as covariate. The assumption of homogeneity of regression was satisfied, F (2, 72) = 46，p >.05, before proceed. Results showed no statistically significant differences among three groups in students' performance in question-generation, F (2, 74) = .045, p>.05.

Table 1. Descriptive statistics on student performance

		SQG* (n=27)	Immediate Scaffolded SQG* (n=26)	Delayed Scaffolded SQG* (n=25)	Total
Science achievement					
	In the prior semester, M (SD)	90.11 (6.65)	90.27 (6.02)	89.56 (7.33)	89.99 (6.6)
	Average midterm, final, M (SD)	85.07(10.46)	85.29(6.24)	81.68(11.9)	81.68 (9.82)
	Adjusted M	84.93	84.96	82.18	
SQG					
	1st QG	4.93(3.40)	8.46(5.56)	3.88 (4.42)	5.76 (4.89)
	8th QG	9.07 (6.28)	11.81(7.23)	8.60 (6.26)	9.83 (6.67)
	Adjusted M	9.60	10.12	9.78	

*SQG: Student Question-Generation

4. Discussion and Conclusions

The present study found no evidence supporting the research hypothesis that scaffolds (introduced immediately or later) in the question-generation process enhanced student performance in science achievement and question- generation. Explanations are provided for the unexpected findings. First, the non-significant result on academic achievement might be due to the overall low cognitive-level type of questions in the midterm and final exams. Further item analysis done on the midterm found that 68% test items were knowledge level and the rest on comprehension level (32%). While 14% of the items in the final exam could be categorized as application (4%), analysis (4%), synthesis (4%) and evaluation (2%), a predominate percentage of test items were still on knowledge (64%) and comprehension (22%). Those items might not allow the deep cognitive-level processing induced during the scaffolded question-generation, as substantiated in King (1990) [9], to manifest its superior effects on learning. On the other hand, the non-significant result in students' performance in question-generation may be because with continuous practice with question-generation for more than two months, students learned from their own experience and the repetitive feedback given by instructors, which lead to no difference in the end.

Though ANCOVA found no differential effects in students' performance in question-generation, a look at the descriptive statistics directed attention to the immediate effects scaffolds had on the task. With guides provided at the 1st question-generation session, students in the scaffolded group performed much better (M = 8.46) than the other two groups (no scaffold, M = 4.93; delayed scaffolds, M = 3.88). In other words, the elevated performance in question-generation of the immediate scaffolded group at the first session, as compare to the no scaffolds and delayed scaffolds, pointed to its immediate effects.

One important implication that can be drawn from this is that instructors concerned about students' initial performance could consider the inclusion of scaffolds at the onset for immediate support. A word of warning, however, is in place.

The set of question stems used in the study was based on a compilation of the work of King (1990) and Tung (2005) [9, 12], followed by instructors' validity assessment, interested instructors as well as researchers are advised to re-assess its relevancy and applicability before including them into specific context. Finally, given the grade and age level of participants in this study and the applied context (science), future studies with other age groups and contents will be needed to warrant its generalizability.

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