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The Comparative Effects of 'What if/what if not' and 'Main Ideas' Scaffolding for Online Student Question-generation on Science Learning

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Abstract: This study examined the effects of two scaffolding types with different levels of structures for student question-generation (SQG) on science learning. Specifically, the comparative effects of the structured 'what-if/what-if-not' scaffolding type and the semi-structured 'main ideas' scaffolding type on science academic achievement and SQG task performance were investigated by a non-equivalent quasi-experimental research method. Students from two sixth-grade classes (n = 56) participated and engaged in a weekly online SQG activity to support science learning for five weeks. An online system was adopted to support the integrated online SQG learning activity. Data analyzed by the multivariate analysis of covariance and analysis of covariance found that the participants in the 'what-if/what-if-not' scaffolding group performed significantly better than those in the 'main ideas' scaffolding group only in the flexibility dimension of student-generated questions. No significant differences were found between the two experimental groups in academic achievement and the other dimensions of student-generated questions task performance (including fluency, originality, and elaboration).

Keywords: Innovative learning and assessment approach, online learning activity, scaffolding, science learning, student-generated questions

1. Introduction

Student question-generation (SQG) is well recognized as an innovative approach to teaching, learning, and assessment (Yu & Wu, 2020). In practice, rather than resorting to teachers posing questions on the instructional material for the assessment of student learning, SQG entails engaging students in the process of question-generation on the study content they personally view as important, relevant, or interesting for self or peer assessment (Yu, 2019). By prompting self-reflection and meaning-making on the part of students, the inclusion and use of SQG in classrooms have been strongly recommended by researchers and practitioners.

Up till now, a wealth of empirical studies has generally substantiated the beneficial effects of SQG for the promotion of various cognitive and affective learning (Rosenshine, Meister, & Chapman, 1996; Rosli, Capraro, & Capraro, 2014; Zuya, 2017). Despite this, researchers have noted difficulties and challenges in the implementation of SQG in classrooms. In an attempt to alleviate SQG implementation hurdles, scaffolding of various types has been proposed. Among these, 'what if/what if not' proposed by Brown and Walter (2005) has been well received whereas 'main ideas' is among one of the most frequently adopted types by researchers (Rosenshine, Meister, & Chapman, 1996).

According to Stoyanova and Ellerton's SQG classification scheme (1996), 'what-if/what-if-not' is the structured SQG type, where students generate questions by the reformulation of given questions to help enhance understanding of the question structure and explore the relationship between questions and answers. 'Main ideas' would be the semi-structured type, where students construct a series of interrelated questions related to unfinished problem structures (e.g., based on a given set of keywords/main ideas) (Stoyanova & Ellerton, 1996). Despite that both 'what-if/what-if-not' and 'main ideas' aim to support students during the process SQG, and their facilitating effects on learning have been confirmed (Brown & Walter, 2005; Rosenshine, Meister, & Chapman, 1996), studies examined if and how students' learning could be affected by scaffolding with different levels of structures for SQG

were scarce. Additionally, for those that did, all adopted a less rigid research method (e.g., one-group experimental research method).

Given that 'what-if/what-if-not' and 'main ideas' as scaffolding for SQG are different in terms of levels of structures (Stoyanova & Ellerton, 1996), which should likely affect the focus, amount, and extent of attention of students, issues regarding if and how they affect learning are the focus of this study. Specifically, the comparative effects of 'what-if/what-if-not' and 'main ideas' scaffolding for online SQG on science academic achievement and task performance are examined.

2. Methods

2.1 The participants, research method, and experimental procedures

A non-equivalent quasi-experimental research design was adopted for this study, with two experimental treatment groups devised — the 'main ideas' online SQG group (i.e., Experimental I group), and the 'what-if/what-if-not' online SQG group (i.e., Experimental II group). Two sixth-grade classes (n=56) from the same elementary school in Tainan city, Taiwan taught by the same science teacher were randomly assigned to the two experimental groups. The SQG activity was introduced to support the teaching and learning of the science unit on 'Simple Machinery' with four subunits: leverages, axles, pulleys, gears, and power transmission.

This study consisted of two main stages and commenced right at the beginning of the spring semester. During Stage I, fundamental knowledge and skills on SQG and the operational procedures for navigating within the adopted online SQG system were introduced before students' hands-on practice session on the system. During this stage, the participants from both groups were directed to generate at least one question for each of the two chosen question types (i.e., short-answer and multiple-choice) on the last unit of the previous semester, and the signal words scaffolding type (i.e., who, what, where, when, what, and how), one of the easily learned scaffolding types for SQG, was introduced to support SQG. The participants' submitted SQG at this stage was analyzed and used as the covariant of SQG task performance whereas the participants' score at the end-of-semester science posttest administered school-wide was collected and analyzed as the covariant of academic achievement.

During Stage II, as a routine, following the instructional session, lab activity, and drill-and-practice sessions on each of the four subunits in the participating school's science lab, the participants reconvened in the school's computer lab during the weekly computer literacy class for the online SQG activity on the respective subunits. To equip the participants of the two experimental groups with the essential knowledge and skills on accessing the respective SQG scaffolding incorporated in the system (see next sub-section), a brief training session was arranged before the participants' first encounter with their respective SQG scaffolding types — the 'main ideas' for the Experimental I group and the 'what-if/what-if-not' for the Experimental II group. After the participants concludes their last online SQG activity on the fourth science subunit, they were tested on the covered content, and their performance at all SQG activity during this stage (i.e., a total of four activities) was assessed.

2.2 The online system

An online system developed under the supervision of the first author of this study (Yu, 2009) was adopted to support the integrated SQG activities. The system allows the content of different types of scaffolding to be dynamically adjusted by the implementing teacher according to the applied context. The space for the two chosen types of questions to be generated as well as examples illustrating how scaffolding for SQG works is depicted in Figures 1 and 2. As shown, for short-answer SQG, for successful submission, students need to complete the question-stem, the answer key, and annotation fields (the middle panel of Figure 1) whereas for multiple-choice SQG, they need to complete the question-stem, four options, the answer key, and annotation fields (the middle panel of Figure 2).

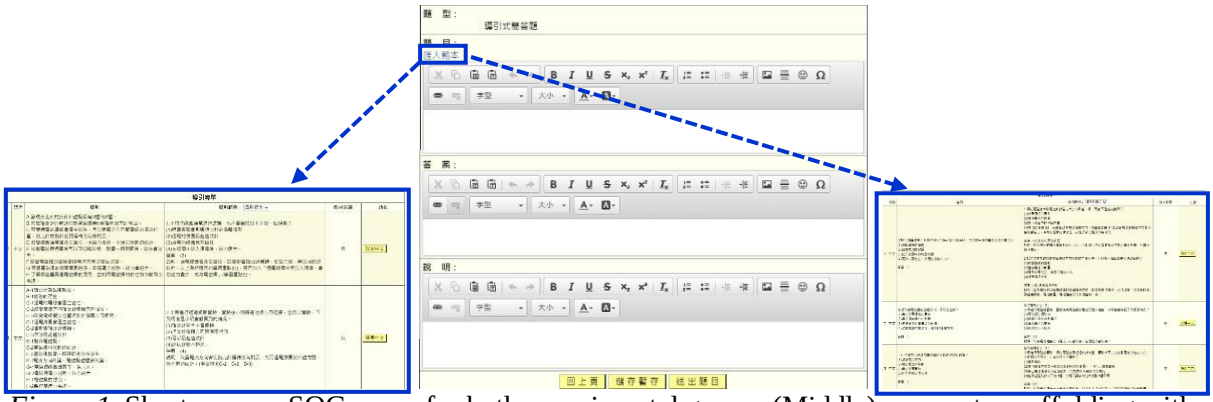

Figure 1. Short-answer SQG space for both experimental groups (Middle); access to scaffolding with examples from the prior unit during Stage I for the 'main ideas' scaffolding group (Left) and for 'what-if/what-if-not' scaffolding group (Right)

To access the scaffolding incorporated in the system for SQG reference, the participants simply click on the hyperlink placed on top of the question-stem field. A pop-up window with either a list of main ideas covered in the current study content (the left panel of Figures 1 and 2) or a list of questions they practiced during the drill-and-practice session developed by the implementing teacher (the right panel of Figures 1 and 2) can be viewed by the participants of the 'main ideas' and what-if/what-if-not' groups, respectively.

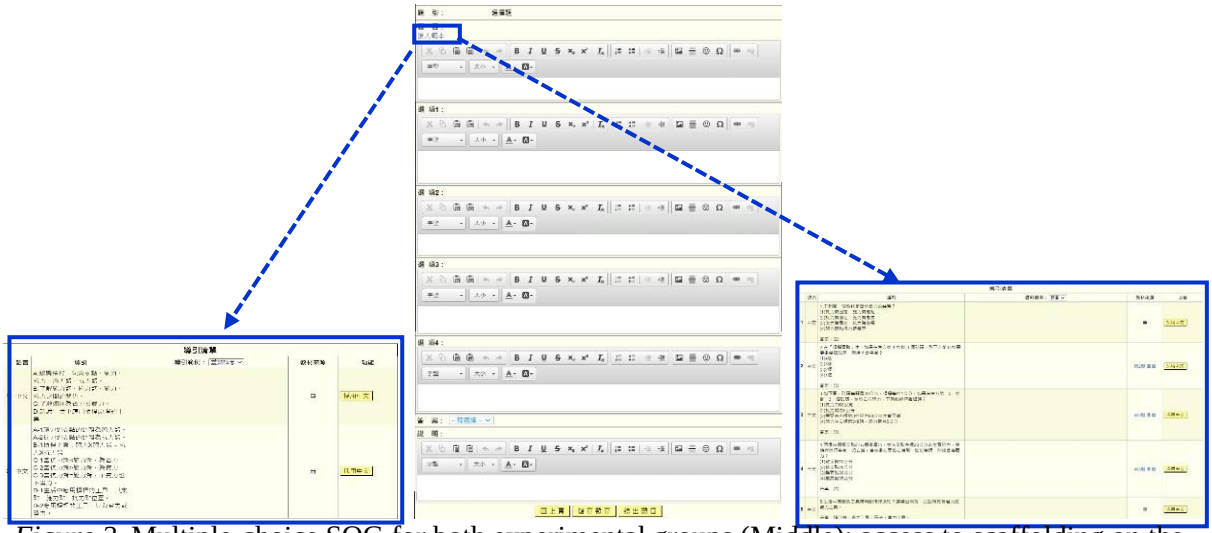

Figure 2. Multiple-choice SQG for both experimental groups (Middle); access to scaffolding on the current subunit during Stage II for the 'main ideas' scaffolding group (Left) and for 'what-if/what-if-not' scaffolding group (Right)

2.3 Measurement instruments

In light of the nature of the science topic, two-tier questions highlighting misconceptions frequently held by students on 'Simple Machinery' (i.e., posttest section I) in addition to the most frequently used question types in classrooms (i.e., posttest section II) were adopted at the posttest. Item analysis procedures with item difficulty and discrimination were conducted for both science academic achievement pretest and posttest to ensure their technical quality. The results evidenced satisfactory item difficulty and discrimination for both tests.

The quality of student-generated questions was assessed according to a set of criteria frequently used for the assessment of SQG performance. Explicitly, all questions the participants generated during Stages I and II of the study (i.e., a total of five SQG activities) were assessed along the four dimensions: fluency, flexibility, originality, and elaboration (Yu & Wu, 2016). Each of the dimensions was operationalized defined. Inter-rater reliability was established.

3. Results and Discussion

3.1 Results

The means and standard deviations of the two experimental groups on the examined variables are listed in Table 1. As a significant correlation was detected between posttest sections I and II, academic achievement was analyzed by the multivariate analysis of covariance technique. The quality of questions (on the four dimensions) was analyzed by the analysis of covariance when assumptions associated with the adopted data analysis methods were satisfied.

The results of data analysis indicated no significant differences between the two experimental groups in academic achievement, Wilks'λ= 0.99, $F(2,52) = 0.25$, $p = .78$, and the fluency, $F(1,53) = 0.12$, $p = .73$, originality, $F(1,53) = 0.07$, $p = .79$, and elaboration, $F(1,53) = 0.42$, $p = .52$ of SQG task performance. Only statistically significant differences in the flexibility dimension of SQG performance were found between the two experimental groups, $F(1,53) = 32.01$, $p = .00$.

Table 1. *Descriptive Statistics of the Two Treatment Groups on the Examined Variables*

Groups (*N*)	Examined variables	*M*	*SD*	Adjusted M
Main ideas (28)	Academic achievement — two-tier test	13.71	1.06	14.75
	posttest	59.64	15.23	62.26
	SQG performance — Fluence	24.93	10.43	25.01
	Flexibility	0.86	1.27	0.85
	Originality	2.61	2.36	2.53
	Elaboration	8.61	4.73	10.04
What-if/what-if (28)	Academic achievement — two-tier test	16.57	1.07	15.54
	posttest	65.79	13.84	63.17
	SQG performance — Fluence	24.25	7.41	24.17
	Flexibility	3.43	1.95	3.44
	Originality	2.29	2.89	2.36
	Elaboration	12.46	6.66	11.03

3.2 Discussion and Conclusion

Attending to and addressing students' misconceptions through innovative teaching strategies are emphasized in science education (Gomez-Zwiep, 2008). As noted by researchers, misconceptions are frequently observed in the teaching and learning of 'Simple Machinery'. In light of the facilitating effects of SQG for the promotion of a deeper understanding of the study content (Yu, 2009), and the overall positive effects of scaffolding on learning in general (Kim, Belland, & Walker, 2018) and SQG task performance in specific (e.g., Yu & Pan, 2014; Yu, Tsai, & Wu, 2013), the comparative effects of two scaffolding effects with different levels of structures, namely 'what-if/what-if-not' and 'main ideas' for SQG, for the support of student learning of 'Simple Machinery' were examined in this study.

Based on the results of data analysis from this study, the more structured 'what-if/what-if-not' scaffolding type did not exert differential learning effects on science learning and most of the indexes of SQG task performance as compared to the 'main ideas' scaffolding type. In fact, the participants exposed to the 'what-if/what-if-not' scaffolding were found to only perform better than the 'main ideas' scaffolding in the flexibility dimension of SQG task performance. In other words, the participants in the 'what-if/what-if-not' SQG group generated significantly more questions containing interlinks among related concepts (either within the current study subunit or to prior subunits) than those in the 'main ideas' group.

In light of the scarcity of studies examining this research question (i.e., if and how students' learning could be affected by scaffolding with different levels of structures for SQG), more studies are

called for. Also, researchers adopting different research method (e.g., qualitative research via in-depth interviews, and non-participant observation, etc.) to explore and understand the underlying mechanism resulting in any observed differences between the two scaffolding types for SQG would be a fruitful future research direction.

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