Computers & Education 94 (2016) 89–101

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

The effects of an online student-constructed test strategy on knowledge construction

Fu-Yun Yu [a], Chun-Ping Wu [b], *

[a] Institute of Education, National Cheng Kung University, No. 1, University Road, Tainan City, 70101, Taiwan
[b] Department of Educational Technology, TamKang University, No.151, Yingzhuan Rd., Danshui Dist., New Taipei City, 251, Taiwan

ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form 16 October 2015
Accepted 17 November 2015
Available online 22 November 2015

Keywords:
Applications in subject areas
Human–computer interface
Improving classroom teaching
Post-secondary education
Teaching/learning strategies

ABSTRACT

The differential effects of online student-constructed tests (SCT) and student-generated questions (SGQ) strategies on knowledge construction in term of the breadth, depth, interconnectivity and elaboration of knowledge were examined via a quasi-experimental research design. Two classes of undergraduates (N = 65) participated and were randomly assigned to two different treatment groups. An online system supporting the associated learning activities for the respective groups was developed. The results from the ANCOVA showed that students who engaged in SCT activities generated questions that covered significantly more concepts, involved significantly more levels of subordinate concepts, and built significantly more links between clusters of study topics, as compared to those in the SGQ group. Moreover, significantly more students in the SCT group engaged in item revision behavior than those in the SGQ group, and a majority of students in the SCT group exhibited item sequencing behavior, both of which are deemed indicative of knowledge elaboration. Suggestions and implications for instructional implementation, online system development and future studies are offered.

1. Introduction

Engaging students in discovering what they view as relevant and important in the material they have learned, and in generating question items around this, have spurred both researcher and practitioner interest since the turn of the 21st century (Yu, 2012). This learning approach, a notable cognitive and meta-cognitive strategy (Rosenshine, Meister, & Chapman, 1996), is known as student-generated questions, problem posing, student item construction, student-developed assessment items, and so on (hereafter called SGQ) (Yu, Wu, & Hung, 2014). While different approaches to SGQ have been proposed to attain specific learning purposes (e.g., structured problem-posing situations for exploring and understanding particular problems, solution structures and interrelationships, see Stoyanova & Ellerton, 1996), and definitions of SGQ vary along with the focal contexts and arrangements (Yu et al., 2014), by emphasizing self-reflection and self-regulated learning, SGQ helps to cultivate a learning environment that prompts and mobilizes higher-order thinking on the part of the learner (Yu & Liu, 2008). To fit the goals and contexts of most levels of school education, SGQ is defined as a learning activity during which students generate a set of questions corresponding to specific previous instruction or experiences they deem educationally important and relevant for self- and peer-assessment purposes.

---

* Corresponding author.
E-mail addresses: fuyun.ncku@gmail.com (F.-Y. Yu), cpwu303@gmail.com (C.-P. Wu).

http://dx.doi.org/10.1016/j.compedu.2015.11.005

The learning benefits of SGQ have been well-documented, and empirical studies on SGQ have generally yielded supportive findings (Akay & Boz, 2010; Belanich, Wisher, & Orvis, 2004; Berry & Chew, 2008; Brown & Walter, 2005; Chin, Brown, & Bruce, 2002; Chiu, Wu, & Cheng, 2013; Dori & Herscovitz, 1999; English, 1997; Kojima & Miwa, 2008; Nardone & Lee, 2011; Perez, 1985; Silver & Cai, 1996; Yu & Liu, 2008). Recently, in an attempt to further promote the versatility and learning potential of SGQ, a group of researchers have been experimenting with the idea of having students construct tests around the study material (i.e., the student-constructed tests approach, called SCT), and have found promising evidence for its support of both learning and assessment. For instance, Yu (2013) investigated undergraduates' preferences for and perceptions of SCT and teacher-constructed tests. The preliminary results showed that the distribution of student preferences for and perceptions of these two approaches were statistically significant at $p < 0.01$ ($X^2 = 48.11$, $X^2 = 22.11$), with more than three-quarters of the participants selecting SCT as their preferred assessment approach and more than 60% of the participants regarding SCT as better promoting learning, highlighting its cognitive and affective potential. Further qualitative analysis of the descriptive responses of participating students after they were exposed to SGQ and SCT activities for a semester underlined the pedagogical potential of SCT for the promotion of knowledge integration and elaboration (Yu & Su, 2013a). Specifically, rather than treating concepts in individual units as capsulated, unrelated parts, SCT helped students to note the integration and inter-connectedness of the study material, and thus to develop a more a '*comprehensive*,' '*integrative*' and '*holistic*' view of the material learned during the course of the study, as a result of '*further review of all course materials*' and '*evaluation of what has been learned as a whole*,' as triggered by the SCT process. Finally, the results from the content analysis of all question items contained in the SCT revealed that nearly three-quarters (74%) of the participants generated items involving cross-topic materials, and almost all students (98%) engaged in item refinement and revision to some extent (Yu & Su, 2013b). The empirical evidence reviewed above all supports the pedagogical potential of SCT on learning.

While SCT emphasizes the same learning goals and concept as SGQ – the promotion of self-reflection and self-regulated learning of the study material and exposed experiences – it involves some planning and preparation in addition to the question-generation task (Corpus, 2013; Devine & Yaghlian, n.d.). Accordingly, on top of the criteria frequently associated with SGQ, such as the clarity of meaning and logic, the relevancy of each question generated, the correctness of wording and punctuation (Yu & Wu, 2013), additional performance criteria, including complete and appropriate coverage of main ideas and adequate item sequencing, are also emphasized during SCT.

Since preliminary studies based mainly on qualitative research methods, and examining the participants' perspectives regarding SCT, have found that a more holistic view of the study content and an integrated and elaborated knowledge structure may be obtained (Yu & Su, 2013a,b), the learning effects of SCT, as compared to SGQ, on knowledge construction were examined in the current study using a more robust research design, a quasi-experimental research method (Shadish & Luellen, 2006), to yield more rigid results and thus serve as the focus of this study. A hypothesis is proposed that SCT may have differential effects on knowledge construction in terms of breadth, depth, interconnectivity, and elaboration of knowledge, as compared to SGQ.

1.1. Theoretical foundations supporting student-constructed test learning activities—cognitive elaboration theory

In terms of the learning tasks that are involved, both SGQ and SCT include question-generation activities intended to engage students in various cognitive and metacognitive strategies, such as attending to and locating materials in the study content that are deemed personally important and relevant; writing questions to assess the targeted learning outcomes; providing answers for the questions that are generated; building linkages between the current study material and previously learned topics/units; creating examples of one's own for any focal concept; deriving plans and strategies for completing the question-generation task in compliance with certain criteria; monitoring comprehension; modifying plans and/or strategies to amend unsatisfactory learning performance at question-generation; and assessing personal understanding of the study material (Yu, 2005; Yu & Hung, 2006). While both information processing and metacognitive theories can help to conceptualize why the mental processes enacted during question-generation (e.g., rehearsal, organization, elaboration, planning, monitoring, revision, and evaluation) may help learners in their cognitive and metacognitive development (Yu & Liu, 2008), the additional tasks and performance criteria associated with SCT may encourage greater and deeper active manipulation of the received information, leading to knowledge growth. In other words, some planning and setting work ahead of and after the question-generation is needed to ensure that the constructed test covers and assesses all subject-matter content of importance, and that all included items are adequately arranged (Corpus, 2013; Devine & Yaghlian, n.d.). In the following sections cognitive elaboration theory is briefly described, followed by its implications for SCT as a learning activity.

Researchers in cognitive psychology have long held to the theory that to aid cognitive processing and structuring, learners must engage in a process that has been labeled cognitive elaboration. Examples of effective elaboration techniques include: re-chunking of content, providing explanatory descriptions or examples, constructing synthesis in various formats (e.g., in prose, graphics, or tabular form), relating newly acquired information to that already stored in the memory, and highlighting critical differences among closely related concepts (Hoffman, 1997; Reigeluth, 1992, 1999; Smith & Savenye, 1991). Studies on elaboration techniques have generally found supportive evidence for their positive effects on memory retention (Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987; Reigeluth, 1983; Seifert, 1994), reading comprehension (Mohammad, 2011; Oh, 2001), and clarification of the relationships among pieces of information (Wittrock, 1978).

During SCT students are asked to carry out some additional learning tasks and alerted to additional performance criteria, and this may activate further cognitive and metacognitive processes of a different nature and intensity, thus promoting knowledge development. To elaborate, SCT involves essentially three sets of cognitive tasks—test-planning, question-generation, and test-setting (see Fig. 1). As a start, students are expected to plan and delimit the scope and overall structure of the study material (i.e., test-planning stage) before moving on to the question-generation stage in accordance with the SGQ criteria. Afterwards, students need to ensure they have produced a set of questions of acceptable quality that adequately cover the study content and are sequenced logically (i.e., test-setting stage) before submitting their work. As can be expected, during the test-setting stage students may return back to the prior stages and engage in the recursive process of test-planning and question-generation (question-revision) if any of the SCT criteria are not met.

In order to ensure comprehensive and balanced coverage of all topics in the study material, during the test-planning stage a number of elaboration techniques are used, such as construction of a summary of the study content in textual, graphical or mental forms (e.g., organizational charts, outlines, and mind maps). Similarly, to ensure that the constructed tests adequately cover the intended cognitive domains of the study material (i.e., remembering, understanding, applying, analyzing, evaluating and creating) (Anderson et al., 2001), organization strategies, such as tables of specification, may be constructed or referred to. Finally, during the test-setting stage, to ensure that question items are sequenced logically, elaboration techniques, such as re-grouping of the items in terms of topic similarity or level of difficulty, can be applied, which may further trigger re-structuring of both the study content as well as one's conceptual organization of it (i.e., one's knowledge structure). The authors thus postulated that it is these additional elaboration processes that students engage in during the test-planning and setting stages of SCT that may further mobilize various cognitive and metacognitive strategies, which in the end should help further cognitive structuring/re-structuring and knowledge construction. Nevertheless, whether SCT has any significant effects on knowledge construction, as compared to SGQ, awaits further research.

2. Methods

2.1. Contexts, participants, research design and implementation procedures

This study took place in the context of an undergraduate advanced core course, Interactive Courseware Design, offered by the Department of Educational Technology in a private university in the northern part of Taiwan. The instructional goal of this course was to cultivate students' knowledge and competence with regard to the development and evaluation of interactive e-Coursewares. Students were expected not only to comprehend but also to apply the studied design principles for the design and development of self-paced e-learning materials and e-assessments.

Sixty-five juniors from two intact classes taught by the same instructor using the same course materials were invited to participate in the study. As developing e-assessments of appropriate quality was deemed an essential skill to be mastered for successful interactive e-Courseware development, the students were instructed to engage in SGQ or SCT as hands-on activities at the conclusion of each of five instructional topics (i.e., interactive test design, message design, problem-based learning strategy, interactive self-paced instructional material design and ARCS theory), which took one to two 3-h instructional sessions, respectively.

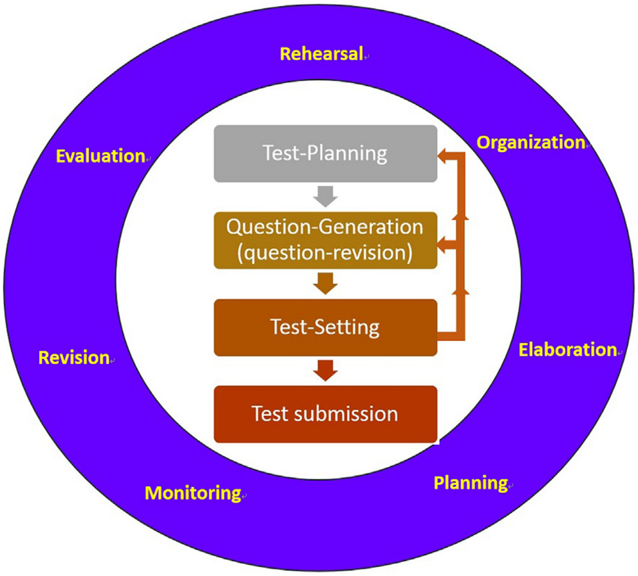


Fig. 1. Cognitive processing and learning tasks activated in SCT with reference to performance criteria.

The experiment was implemented for eight weeks. A quasi-experimental research design was adopted. Two participating classes were randomly assigned to the two treatment conditions—SGQ and SCT. Both groups were given the scenario that several adult learners were going to be evaluated on their learning of the same contents they just studied. Both groups thus had to develop an e-assessment tool for the content. Specifically, in the SGQ group students were required to generate five to seven multiple-choice question items in accordance with each of the five instructional topics, whereas in the SCT group students were directed to construct a test consisting of five to seven multiple-choice question items covering the same instructional content.

The experimental procedures, including the training and intervention implementation, are depicted in Fig. 2. To equip participants with the knowledge and skills associated with the tasks, a training session was provided for both groups. During the training session, quality criteria for SGQ and SCT were introduced and explained to the respective treatment groups. The performance criteria used for question-generation include: validity (i.e., items matched with learning objectives), addressing the main ideas of the study material, assessing both instruction-based fundamental knowledge and extra-instruction materials covered by the instructor, of appropriate discrimination value, clear wording and expression, of suitable difficulty level, matched with student level of capability, and the examples given in questions are at a suitable difficulty level. In addition to the SGQ criteria, an additional set of criteria were given to the SCT group, focusing on overall coverage and appropriate distribution of all important topics, and adequate sequencing of item in terms of difficulty level. The additional criteria given to the SCT group are as follows: the number of items on a topic in a test are proportionate to its importance (with more items included for more important topics), items assess different cognitive levels, items are sequenced from easy to difficult, containing neither too difficult nor too easy items. Model questions and tests were presented to both groups to enhance students' understanding of these criteria. Additionally, the features and operational procedures of the system adopted in this work were demonstrated, followed up by hands-on practice activities on question-generation or test-construction. Afterwards, whole class feedback on the students' practice was given by the teacher. For the SGQ group, ten exemplary student questions were presented to the class, by highlighting their strengths in accordance with the quality criteria, followed up by whole class discussion of possible ways to enhance the quality of a focal item. The same procedures for whole class feedback were used with the SCT group, but both model questions and tests were presented.

During the intervention implementation stage, for each of the five online learning activities, whole-class feedback for student performance on the previous online learning activity was arranged before the class received instruction on the focal topic. Afterwards, the students were directed to login to the online system and start working with the question-generation sub-system to generate questions based on the focal instructional topic. The students then moved on to the question-management sub-system, where they could revise and delete any questions that they wanted to, and then export the finished work in.pdf file, while selecting and sequencing items in a test and accessing the additional set of criteria were only carried out by the SCT group (see next section for details).

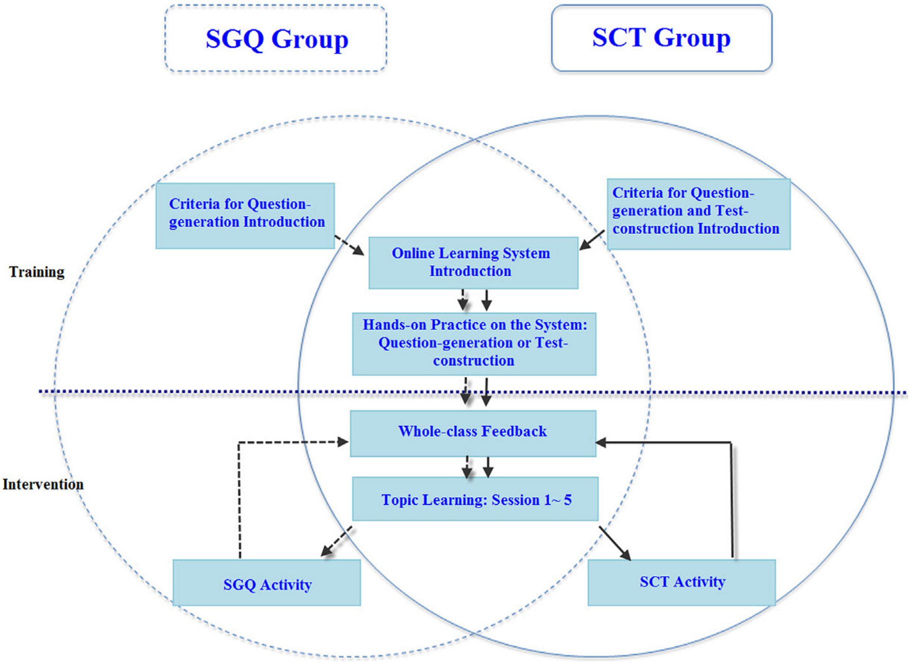


Fig. 2. Experimental procedures for this study.

2.2. *The online learning system*

2.2.1. *Design principles*

A web-based learning system was developed to support the question-generation and test construction activities, and this had the advantages of being able to present multimedia content, and allow updating and managing of content without time, space and learning device constraints. This process followed an explicit set of design principles, as explained below.

First, to enhance accessibility and operability, the online learning system is browser-based, and can be run using standard web technologies. The users can work on the learning tasks on the system using different devices, web browsers and operating systems via the Internet, at anytime and anywhere. Video files can also be viewed without the need for additional hardware or programs to be installed on user devices.

Second, to enable users to present the complex scenarios and dynamic relationships among pieces of knowledge, the system allows users to embed multimedia files, including graphics, animations, and videos, as part of the question (see the upper-left part of Fig. 3). To enhance ease of operation, any uploaded video files are automatically reformatted with a built-in control panel for instant viewing by the question-author.

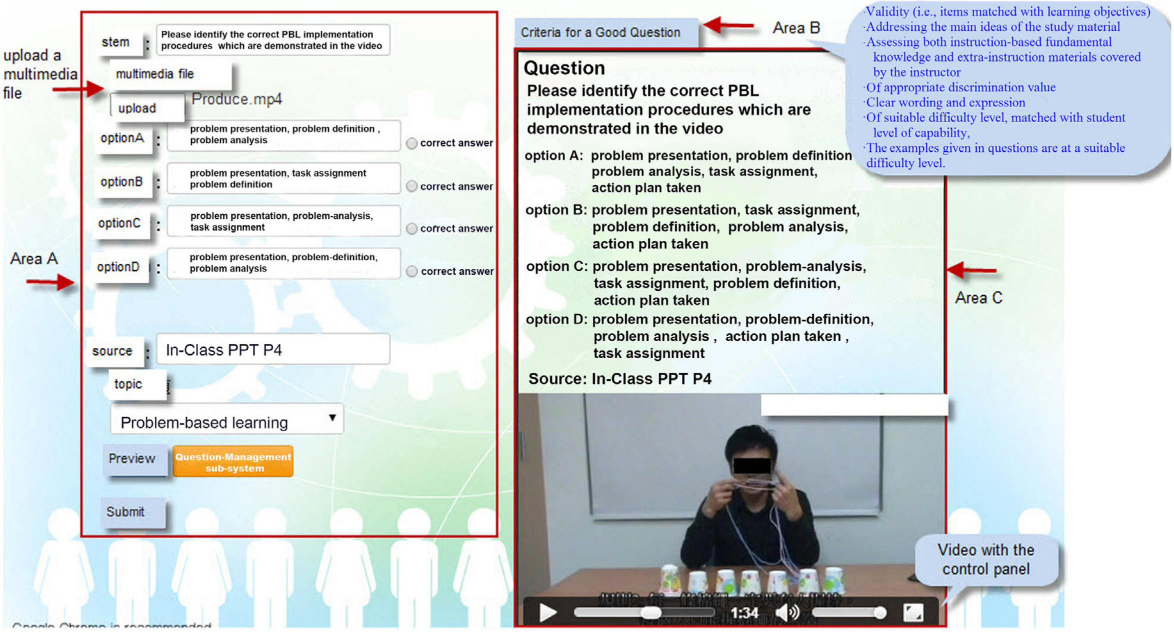
Third, to adhere to Mayer's spatial and temporal contiguity principles (2010) (i.e., multimedia should be placed close to the related texts and at the same time), any multimedia files used as part of the questions can be viewed with other question content in the same window, rather than being watched in another pop-up window. In addition, a preview feature is built in to allow users to preview and edit the questions in the same learning space.

Fourth, to allow easy management and use of user content, users are allowed to access, revise, add and delete questions and re-arrange question sequence via the online question-management function (see the next section on learning space for details). In addition, the system also allows the users to export their final work (i.e., generated questions or constructed tests) in a portable file format (i.e.,.pdf) for future reference and use.

Fifth, to provide learning support on a timely basis, the criteria for a good question and test are provided in the question-generation and test–construction interface, respectively (see Area B in Fig. 3 and Icon A in Fig. 4), as the majority of the participants were inexperienced with regard to the learning task. Furthermore, to respect individual learning needs and preferences, the quality criteria content is designed as a pop-up window to be shown only if the related activation button is clicked.

2.2.2. *Online learning spaces*

According to the set of design principles, two learning sub-systems were developed to engage students in the introduced learning tasks, and were made available to both the SGQ and SCT groups. First, the question-generation sub-system (Fig. 3) allows users to create multi-choice questions and to preview them. Users type in a question item and four options and designate the correct answer for each question generated in Area A (left panel, Fig. 3). The criteria for a good question can be



stem : Please identify the correct PBL implementation procedures which are demonstrated in the video

Produce.mp4

optionA : problem presentation, problem definition , problem analysis ○ correct answer

optionB : problem presentation, task assignment problem definition ○ correct answer

optionC : problem presentation, problem-analysis, task assignment ○ correct answer

optionD : problem presentation, problem-definition, problem analysis ○ correct answer

source : In-Class PPT P4

topic : Problem-based learning

·Validity (i.e., items matched with learning objectives)
·Addressing the main ideas of the study material
·Assessing both instruction-based fundamental knowledge and extra-instruction materials covered by the instructor
·Of appropriate discrimination value
·Clear wording and expression
·Of suitable difficulty level, matched with student level of capability,
·The examples given in questions are at a suitable difficulty level.

Question

Please identify the correct PBL implementation procedures which are demonstrated in the video

option A: problem presentation, problem definition problem analysis, task assignment, action plan taken

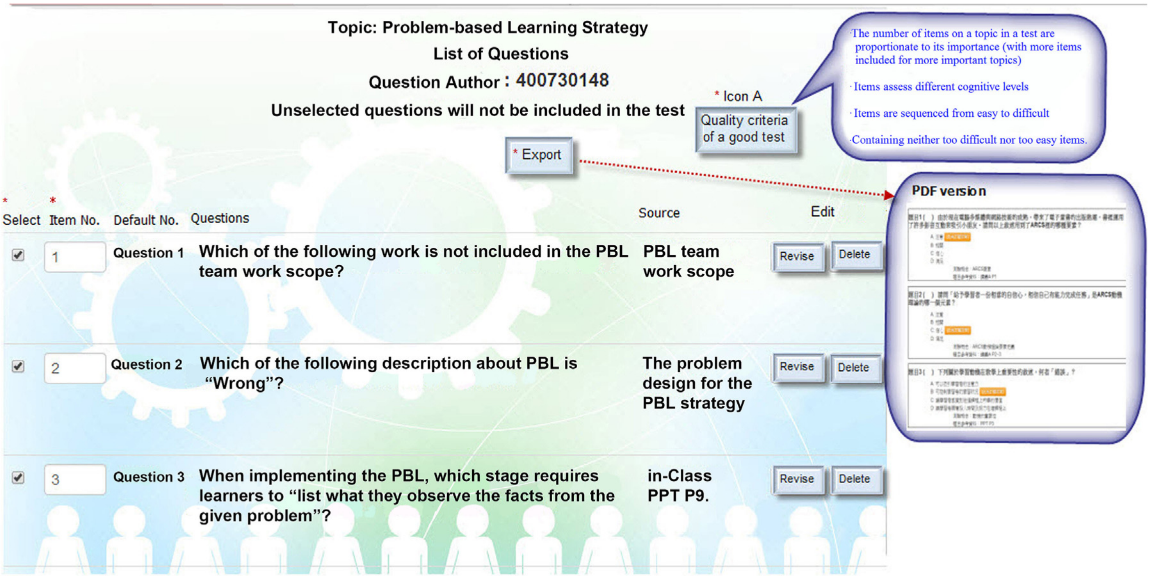
option B: problem presentation, task assignment, problem definition, problem analysis, action plan taken

option C: problem presentation, problem-analysis, task assignment, problem definition, action plan taken

option D: problem presentation, problem-definition, problem analysis , action plan taken , task assignment

Source: In-Class PPT P4

Fig. 3. A screenshot of the question-generation sub-system for the SGQ and SCT groups.



Topic: Problem-based Learning Strategy

List of Questions

Question Author : 400730148

Unselected questions will not be included in the test

* Export

* Icon A

Quality criteria of a good test

- The number of items on a topic in a test are proportionate to its importance (with more items included for more important topics)
- Items assess different cognitive levels
- Items are sequenced from easy to difficult
- Containing neither too difficult nor too easy items.

PDF version

* Select	* Item No.	Default No.	Questions	Source	Edit	
☑	1	Question 1	Which of the following work is not included in the PBL team work scope?	PBL team work scope	Revise	Delete
☑	2	Question 2	Which of the following description about PBL is "Wrong"?	The problem design for the PBL strategy	Revise	Delete
☑	3	Question 3	When implementing the PBL, which stage requires learners to "list what they observe the facts from the given problem"?	in-Class PPT P9.	Revise	Delete

Note: The symbol of * denotes the four features especially developed for the SCT group

Fig. 4. A screenshot of the question-management sub-system for the SGQ and SCT groups.

accessed via a built-in button (marked as Area B, upper-right corner of Fig. 3). Area C (right panel, Fig. 3) is reserved for question previews, and a control panel is provided beneath the video-playing screen.

Second, the question-management sub-system was developed (see Fig. 4) to allow both groups to access, revise, and delete the questions they have generated, and export their final submission in a portable file format. Three additional features are provided for the SCT group: item inclusion (via clicking on the "Select" function), item sequencing (by designating the order in which items are presented in a test in the "Item No." column), and an additional set of criteria for test construction (by clicking on icon A, upper-right corner).

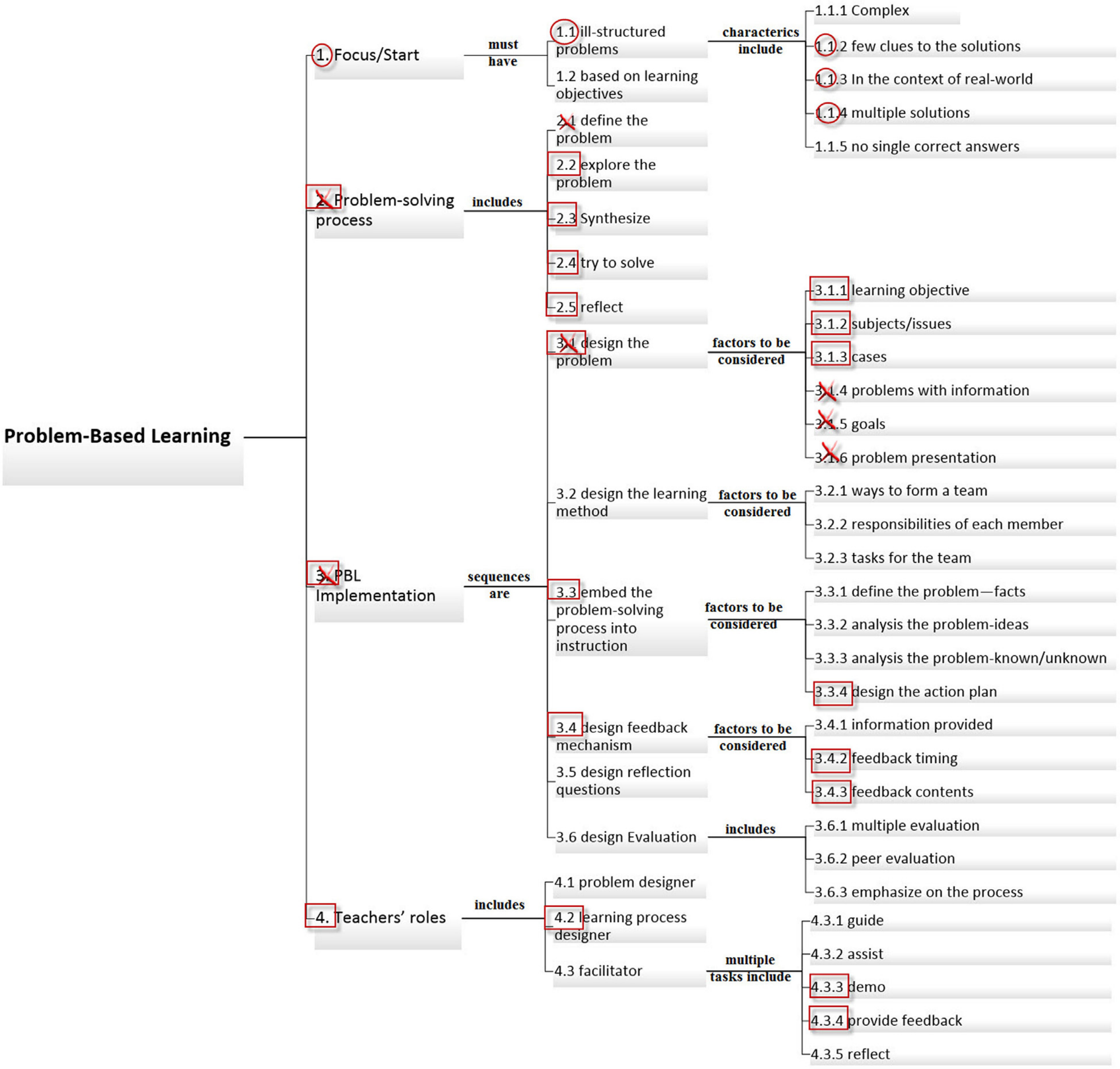
2.3. *Measurement instruments*

For the purposes of this study, a set of coding instruments (i.e., expert concept-maps), coding procedures, and coding index were devised, and these are explained below.

To examine the different effects of SCT and SGQ on knowledge construction, questions were coded in terms of the concepts contained in the expert concept-maps. One expert map was created by the instructor for each of the five instructional topics, depicting all important concepts, sub-concepts and their relationships, for use in coding. As illustrated in Fig. 5, the PBL topic has four main concepts, which are placed on the first level of the map and coded 1, 2, 3, and 4 to constitute one set/branch/hub/cluster of the concept-map, respectively. Main concept 1 is composed of two subordinate concepts, which are then placed on the second level and coded 1.1 and 1.2. The five sub-concepts subordinated to concept 1.1 are then placed on the third level and coded 1.1.1 to 1.1.5, respectively. As can be seen, the number of digits associated with a concept denotes the number of levels it was placed on.

The coding tasks were performed by two independent raters with substantial knowledge about the focal instructional topics. The raters identified the concepts and sub-concepts being tested in each question generated by each of the students for each of the five instructional topics by highlighting them (via circling, squaring, or crossing-out) on the expert concept-maps in a student-by-student fashion. As a result, a total of 310 concept-maps were created (with fifteen missing copies due to absentees). To ensure the two raters understood and correctly interpreted the coding scheme, for reliability purposes all questions generated by both participating groups for one activity were independently coded and compared. Any inconsistencies in the resulting codings were resolved between the raters. Furthermore, five students were randomly selected from the experimental groups, and their work on two learning activities was independently coded and compared. When 100% consistency with regard to the coding carried out by the two raters was achieved, they proceeded to the rest of the coding tasks.

With reference to the work of Novak and Gowin (1984) on concept-mapping, a set of indexes, including node numbers, hierarchical levels and cross-overs, which are widely adopted as indicators of knowledge structure and construction (e.g., Lee, Jang, & Kang, 2015; McClure, Sonak, & Suen, 1999; Reiska, Cañas, Novak, & Miller, 2008; Rice, Ryan, & Samson, 1998; Walker & King., 2003; West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000), were devised, and these are explained as follows:



Note: 1. The concepts and sub-concepts being tested in each question were highlighted using different symbols. For example, concepts being tested in question1, 2, and 3 were highlighted using a circle, ○, cross-out, ✗ and square, ▭, respectively.
2. The highlighted symbols were placed around the number located above the concepts.

Fig. 5. An illustrative example of the coding scheme.

First of all, the total number of concepts (i.e., represented as nodes in the concept-maps) covered by the questions generated was adopted as an index of knowledge breadth. The total number of highlighted coded numbers was thus counted to reveal the knowledge breath of the students engaged in either the SQG or SCT activities.

Second, as a convention of concept-mapping, the most general, abstract, broad, inclusive concepts are placed at the top of a map, and the most specific, subordinate concepts are placed at the bottom (Novak & Gowin, 1984). Since the extent of generality/specificity is differentiated and represented by the levels of hierarchies in different sets/branches/hubs/clusters of a concept-map, hierarchical levels were used in this study to represent the depth of knowledge. To take into account that each of the main concepts may consist of different hierarchical levels, the total number of hierarchical levels in each concept-map is obtained by adding up the number of hierarchical levels in each of the main concepts (i.e., sets/branches/hubs/clusters). To calculate the hierarchical levels in this study, the links connecting the first and lowest levels of the highlighted coded numbers belonging to the same set/branch/hub/cluster were first identified. As shown in Fig. 5, two hierarchical levels could be observed for main concept 1 (i.e., the links between nodes 1.1.2 and 1.1, and between nodes 1.1 and 1). The numbers of hierarchical levels in the different sets/branches/hubs/clusters were then added (i.e., 2 + 1+2 + 2 = 7, as shown in the illustrated case in Fig. 5).

Third, because cross-over connects concepts placed in different sets/branches/hubs/clusters of a map, it was adopted to illustrate the extent of inter-connectivity of concepts in the study topic covered by a question. For calculation purposes, for each generated question the issue of "whether any connections between concepts located in different sets/branches/hubs/clusters were formed" is assessed first. If the answer is yes, the number of sets/branches/hubs/clusters crossed is tallied. The number of cross-overs present in the different questions generated by a student are then added up to represent the extent of inter-connectivity of the concepts on the topic. As shown in Fig. 5, to differentiate concepts covered in different questions, different shapes (i.e., circled, crossed-out, and squared nodes) were used for coding purposes. For question 1, because all numbers coded with a circle stayed in the same set/branch/hub/cluster (i.e., main concept 1), no cross-overs were observed. For question 2, several numbers coded with a crossed-out shape were present in main concepts 2 and 3 (i.e., 2, 2.1, 3, 3.1, 3.1.4, 3.1.5, and 3.1.6), and thus one cross-over was counted (i.e., that between main concepts 2 and 3). For question 3, several numbers coded with a square shape were present in the main concepts 2, 3, and 4, and thus three cross-overs were counted (i.e., cross-overs between 2 and 3, 2 and 4, and 3 and 4). As a result, the total number of cross-overs present in the three questions were added together (i.e., 0 + 1+3 = 4, as shown in the illustrated case in Fig. 5).

In addition, data on item revision (i.e., the number of persons who engaged in question-revision behavior) and item sequencing (i.e., whether or not questions were re-sequenced before final submission) were retrieved from the database, counted and taken as an index of knowledge elaboration in this study. This definition is based on the realization that, to some extent, each question item can be viewed as a piece of knowledge produced from and by the student, while a test composed of a set of question items represents the knowledge landscape of the student with regard to the focal topic.

2.4. *Data analysis*

To examine if there are significant differences in the number of nodes, hierarchical levels, and cross-overs between the two treatment groups, an analysis of covariance (ANCOVA) was adopted. To take into account the fact that questions generated by students (SGQs) may not be complete and correct (Yu & Chen, 2014), the quality of SGQs was evaluated using the fluency criteria (i.e., clarity of the meaning and logic of the questions) (Yu & Wu, 2013). Only questions meeting the fluency criteria were included in the followed up data analysis. As a result, 1423 question items were included in the data-analysis after deleting 26 disqualified items.

The number of questions students generated in the first week of the experimental implementation was used as the co-variate to take into account the participants' pre-existing differences in question-generation abilities. The assumptions of homogeneity of the variances and regression were satisfied before conducting the ANCOVA. Furthermore, a chi-square test of homogeneity was used to determine whether the number of participants engaged in question revision behavior was distributed similarly across the SGQ and SCT groups. Finally, descriptive statistics were used to examine the extent to which SCT activities directed students to engage in item sequencing in the tests.

3. Results

As shown in Table 1, the total number of nodes covered in all questions generated by the SCT group is 54.23, which is higher than that generated by the SGQ group (M = 42.17). Both of the assumptions of homogeneity of the variances and regression were satisfied ($F = 3.67$, $p > 0.05$; $F = 0.38$, $p > 0.05$, respectively), before proceeding to the ANCOVA. The results of the ANCOVA showed significant differences in the number of nodes covered between the two groups, $F = 6.27$, $p < 0.05$.

As for the hierarchical levels, 32.02 levels were observed for the SCT group. This is more than the 25.53 levels observed in the SGQ group (see Table 1). The assumptions of homogeneity of the variances and regression were not violated ($F = 0.43$, $p > 0.05$; $F = 0.07$, $p > 0.05$), and the statistically significant difference in hierarchical levels between the two groups was supported by the ANCOVA results, $F = 8.49$, $p < 0.05$.

Regarding cross-overs, 6.91 were obtained by the SCT group, which was more than the 5.17 cross-overs obtained by the SGQ group. Both the assumptions of homogeneity of the variances and regression were satisfied ($F = 0.35$, $p > 0.05$; $F = 0.16$, $p > 0.05$). The ANCOVA results showed significant differences between the two groups, $F = 7.54$, $p < 0.05$.

With regard to question-revision behavior, the average number of participants who engaged in this was 14.2 per week for the SCT group and 7.8 for the SGQ group. The results of the chi-square test of homogeneity showed significant differences

Table 1
Descriptive statistics of the examined variables for the two treatment groups.

Treatment groups	The SCT (n = 35)	The SGQ (n = 30)
Examined Variables	M (SD)	M (SD)
Covariance[a]	5.03 (1.07)	4.9 (0.66)
Number of nodes covered	54.23 (21.64)	42.17 (15.34)
Hierarchy levels	32.02 (8.64)	25.53 (9.08)
Cross-overs	6.91 (2.58)	5.17 (2 0.45)

[a] Number of questions submitted in the first week.

between the observed frequencies of the two groups, $X^2 = 7.66$, $p < 0.05$, indicating that the two groups differed significantly with regard to the proportion of participants exhibiting versus not exhibiting item revision behavior.

Finally, although the number of students assigned to the SCT group engaged in item-sequencing behavior fluctuated from activity to activity (37, 18, 25, 24 and 20 for the 1st to 5th activities), on average, more than 70% (70.29% to be exact) re-arranged item sequences before test submission.

4. Discussion and conclusions

Based on the results of the data analysis, it was found that concepts covered in questions generated by the SCT group enclosed significantly more nodes, reached significantly more hierarchical levels, and created significantly more cross-overs, as compared to those of the SGQ group. In other words, the students who engaged in the SCT activities tended to generate questions that not only covered significantly more concepts with regard to the study material, but also involved significantly more levels of specific, subordinate connected concepts, and these students built significantly more links among different clusters of topics, in comparison to their counterparts in the SGQ group. As suggested by a number of researchers (e.g., Hoeft et al., 2003; McClure et al., 1999; Novak & Gowin, 1984), cross-links between concepts, including the hierarchical links between subordinated concepts and links between different segments or domains of knowledge in concept-maps, could be a valid and reliable indicator for students' integrative and in-depth understanding of the learning content. It can thus be reasonably inferred that the SCT promoted better knowledge integration and integrative reconciliation of the meaning of the content, as compared to SGQ.

Moreover, it was found that a significantly larger proportion of students in the SCT group engaged in item-revision behavior as compared to those in the SGQ group, and that a majority of students in the former utilized the built-in item-sequencing function to re-sequence questions for their inclusion in a test. Because both item-revision and re-sequencing behavior involve various types and extents of cognitive adjustments and fine-tuning to meet the task criteria (e.g., assessing and clarifying the completeness, correctness, appropriateness, similarity, and difficulty of different pieces of knowledge contained in the study material, and making amendments accordingly, which are indicators of knowledge elaboration), SCT was shown to encourage students to be more involved in the refinement of their knowledge.

As noted above, when engaged in SCT, as in SQG, the students were given opportunities to generate questions around the study material they regarded as important and relevant, which induced them to engage in learning tasks, such as providing illustrative examples or explanatory descriptions, and relating to or contrasting entities with close structural resemblances or conceptual similarities. These processes demand the activation of various cognitive and metacognitive strategies (Yu, 2012). Nevertheless, on top of this, SCT directs students' attention to additional criteria, such as complete coverage of main ideas, different weightings of test items in accordance to the relative importance of various main ideas covered, and the appropriateness of item sequencing, which may stimulate further and deeper cognitive processing. In other words, when working toward the goal of test construction students are involved in a number of additional learning tasks during the test-planning and test-setting stages, which are more likely to stimulate further cognitive processing. The processes that are enacted may include the following:

- Re-examining the overall content of the learned materials for scope management and possible connection-building between and among clusters of pieces of knowledge.
- Constructing a summary or synthesis in the students' preferred forms, with all important topics delineated.
- Engaging in an iterative process of test-planning and question-generation (question-revision) to ensure a comprehensive and balanced representation of all important topics in the test, which may trigger further linkages to be developed among concepts, both within and between clusters of concepts.
- Assessing the relative importance and difficulty level of different concepts to ensure their adequate representation in the constructed test, which, as a consequence, may prompt further knowledge structuring and restructuring.

As implied by cognitive elaboration theory, by stimulating the mobilization of elaborative techniques and activating the iterative process of test-planning, question-generation (question-revision), and test-setting to fit the test construction performance criteria, the cognitive processes that occur during the SCT activity, as reflected in the results of this study, lead to more interconnections being developed among the important concepts, thus supporting knowledge construction on the part of the learner to a greater extent than seen with SGQ.

4.1. *Significance of the study*

The current study has empirical, instructional, and methodological significance. First, while the learning potential of SCT for the promotion of knowledge integration and elaboration has been suggested in prior works (Yu & Su, 2013a,b), existing research is mainly based on preliminary studies adopting qualitative research methods to examine students' perspectives on SCT. By adopting a quasi-experimental research method to examine the comparative effects of SGQ and SCT on knowledge construction, the current study yielded more substantial evidence on SCT's positive effects on the breadth, depth, interconnectivity, and elaboration of knowledge.

Second, due to the positive learning effects of elaboration techniques, a set of these has been proposed and tested in the literature (Mohammad, 2011; Oh, 2001; Reigeluth, 1983; Wittrock, 1978). The current study helps to expand this set of elaboration techniques, and also indicates that SCT is a viable approach for knowledge elaboration.

Finally, positive effects of SGQ on knowledge construction were implied. However, no measurement systems have yet been devised for this. With reference to research on concept-mapping in relation to measurement instruments and student learning (e.g., Hoeft et al., 2003; McClure et al., 1999), a coding index and a framework for knowledge construction were proposed in this study. The index associated with concept-mapping has been applied almost exclusively to examine student knowledge development as a result of formal instruction with descriptive texts, and its application to SGQ in this study (and also to the students' learning experience using descriptive texts as the main learning material) was experimental and may be a matter of dispute. Nevertheless, the proposed index and framework can be referred to and adopted by researchers and practitioners as learning assessment tools to better understand student knowledge structure and development as a result of SGQ, SCT activities, or any learning strategies that have the construction of construction as a focus.

4.2. Limitations of the study

This study has the following limitations. First, and as described in the main body of the text, the SGQ and SCT learning activities were introduced to help students to develop their knowledge and competence related to interactive courseware design. In consideration of the real-world performance context, students in both groups were directed to generate a set of five to seven question items, which were intended as embedded questions for e-assessments to be used by peers in self-paced interactive online learning systems. The constraint imposed on the number of questions to be generated per session may have limited the generalizability of the results found to traditional classrooms with regard to paper-and-pencil assessment formats, where the number of question items included is less of a concern.

Second, since the context of this study is interactive courseware design for self-paced e-learning materials and e-assessments, multiple-choice questions were the type that needed to be generated. It has been suggested that different types of questions have different strengths and limitations (Yu & Li, 2011), and the literature on test construction has shown that generating different types of questions may engender different cognitive processes and behavioral responses, and may exert different demands on cognitive capacity (Maki, 1998; Pressley, Ghatala, Woloshyn, & Pirie, 1990). The generalizability of the findings of this study to others involving different question types should thus be carried out with caution.

Third, although the fluency criteria were used to exclude some items from the data analysis, readers should be aware that this study only targeted questions generated by students without referring to other learning outcomes (e.g., their performance on the focal e-course), and that the analysis of questions mainly focused on the concepts covered in these, and the number of revisions made by students to them, without any in-depth analysis of the quality of the questions in terms of other dimensions (e.g., complexity, originality, and cognitive level) (Yu & Wu, 2013).

Finally, the presence versus absence of item-revision and item re-sequencing were arbitrarily defined as indicators of knowledge elaboration in this study. Since revisions may involve different types (e.g., correction of words or phrases, adding or changing the illustrative examples, re-arrangement of alternatives in a questions) and extents (i.e., number of revisions), further analysis along these lines may shed more light on this issue.

4.3. Suggestions of the study for instructional implementation

Based on the results of this study and the wide range of empirical evidence supporting the positive effects of SGQ on learning (Belanich et al., 2004; Brown & Walter, 2005; Chin et al., 2002; Dori & Herscovitz, 1999; English, 1997; Kojima & Miwa, 2008; Perez, 1985; Rosenshine et al., 1996; Silver & Cai, 1996; Yu & Liu, 2008), it is suggested that instructors can consider adopting an SCT strategy following SGQ learning activities to further promote student knowledge construction. Nevertheless, to ensure that the potential of SCT can be achieved, some practices that were applied in this study may be essential. These include: clearly explaining the performance criteria for the SCT task with model questions and tests, demonstrating and allowing students to have hands-on practice with the SCT task prior to the SCT activity (to reduce any extraneous cognitive load that the task may impose on the learner), and providing feedback on students' practice to enhance their knowledge of the SCT task, thus maximizing the potential of the SCT strategy with regard to enhancing knowledge construction.

Furthermore, in order to extend the potential of SCT to other contexts (beyond the current one involving only undergraduate students) while mitigating certain challenges that may inadvertently overload learners to the extent of negatively affecting learning performance, more work may be needed to support the implementation of SCT. Some suggestions with regard to this are provided below:

First of all, additional training on how to summarize and organize the study content in different forms (e.g., organizational charts, outlines, structural maps, content trees, and mind maps) may be arranged to help students to benefit from the activity.

Second, for students with limited cognitive capacities or other specific characteristics (e.g., younger children who have not reached the formal operational stage, field-dependent learners or those with a local level cognitive style in which structures or information between cognitive categories cannot be easily abstracted) (Sternberg, 1997), supportive scaffolding (Jackson, Krajcik, & Soloway, 1998), or conceptual scaffolding (Hannafin, Land, & Oliver, 1999) may be given directly to provide advice and guidance. For instance, a summary of the study content delimiting and depicting the main ideas of the study material in bullet points or graphical forms can be accessed and used by students with different learning preferences or cognitive styles, thus providing support for the SCT task at the learners' discretion.

Third, procedural prompts to help the learners (Ge & Land, 2004) complete the three sets of cognitive tasks involved in SCT (i.e., test-planning, question-generation, and test-setting) can be provided to help orient students to the flow of the task.

Fourth, to ensure that the set of criteria associated with question-generation and test construction tasks act as intended, their comprehensibility and appropriateness for the targeted group of learners (i.e., in terms of age and educational level) should be attended to. In other words, the exact wording of each of the criteria for SGQ and SCT should be tailored to the context in which they are to be applied.

Fifth, to avoid cognitive overload when working on the SCT task, the number of questions in each question-generation activity should be determined with reference to the students' achievement levels, the complexity of the focal content, and the time that can be allocated for the SCT activity.

Lastly, while providing explicit support may not be essential, for cognitively mature or independent learners, reflective scaffolding (Jackson et al., 1998) or metacognitive scaffolding (Hannafin et al., 1999) may be helpful to prompt learners to reflect, plan, and manage their individual thinking processes and the SCT task, so that they can mobilize the necessary cognitive processes and achieve more successful outcomes.

4.4. Suggestions for system development and future studies

In view of SGQ's pedagogical value, there are currently more than a dozen online learning systems equipped with various affordances of networked technologies to support SGQ activities (Yu & Wu, 2012). However, to the best of the authors' knowledge, systems supporting SCT learning activities have yet to be fully assessed, and few new ones are being developed (Yu, 2013). Developers interested in SGQ are thus strongly encouraged to consider the development of a test construction component in addition to question-generation, to further advance the cognitive effects of SGQ, as attested in the study.

As for future research topics, the following five directions are suggested here. First of all, the current study involved undergraduate students taking a course with a focus on the development of interactive courseware design, and it lasted eight weeks. Future studies involving different contexts (e.g., age groups, domains, and traditional course formats) and lasting for longer durations of time would be needed to establish the external generalizability of this study.

Second, the current study examined the comparative effects of SCT and SGQ on knowledge construction by analyzing the questions composed by the students, and asked the students to create one specific type of questions—multiple-choice. In addition to investigating the comparative learning effects of educational importance (e.g., academic achievement, the use of cognitive and metacognitive strategies, and levels of reflection), studies involving other types of questions should also be conducted.

Third, future studies could adopt a qualitative research approach to analyzing the type and extent of item revision, and thus a more elaborated analysis scheme may be developed. The use of a data-driven definition of knowledge elaboration for data analysis should help shed more light on the comparative effects of SGQ and SCT on knowledge construction.

Fourth, students may approach the tasks differently when engaged in SCT, which may be contingent upon individual differences in cognitive style (such as the legislative, executive or judicial functions of thinking styles, as referenced in Sternberg's 1997 taxonomy of cognitive styles). Also, in light of the additional learning tasks and criteria associated with SCT (each involving some degree of complexity, and demanding the allocation of some cognitive capacity from the learner), individual differences in question-generation ability, past experience with question-generation, and achievement levels may exert some effects on learning outcomes. As such, issues pertaining to any interaction effects SCT may have with personal factors would be a research topic of interest to both instructors as well as researchers, in order to provide differentiated instruction, as needed.

Fifth, the current study compared the effects of SCT and SGQ on knowledge construction by only examining those questions which satisfied the fluency criteria. Future studies may also investigate whether the quality of students' questions could predict their knowledge construction in terms of the breadth, depth, and interconnectivity.

Finally, as revealed in prior studies, many students lack prior experience in SGQ (Moses, Bjork, & Goldenberg, 1993; Vreman-de Olde & de Jong, 2004), consider SGQ difficult (Yu, 2009) or have concerns about their capabilities as they relate to SGQ (Yu & Liu, 2005). Since SCT involves more complex tasks as compared to SGQ, developing a set of theoretically-sound online scaffolds in various forms to support SCT learning activities (either with the support of technology via online prompts, or peers via cooperative learning), and establishing the efficacy of each of these support mechanisms, would be another research project worth focusing on.

Acknowledgments

This paper was supported by two research grants funded by the Ministry of Science and Technology, Taiwan (NSC 102-2511-S-006-003-MY3 & MOST 103-2511-S-032 -007).

References

Akay, H., & Boz, N. (2010). The effect of problem posing oriented analyses-II course on the attitudes toward mathematics and mathematics self-efficacy of elementary prospective mathematics teachers. *Australian Journal of Teacher Education, 35*(1), 59–75.

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., et al. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York, NY: Pearson, Allyn & Bacon.

Belanich, J., Wisher, R. A., & Orvis, K. L. (2004). A question-collaboration approach to web-based learning. *American Journal of Distance Education, 18*(3), 169–185.

Berry, J. W., & Chew, S. L. (2008). Improving learning through interventions of student-generated questions and concept maps. *Teaching of Psychology, 35*, 305–312.

Brown, S. I., & Walter, M. I. (2005). *The art of problem posing* (3rd ed.). New Jersey: Lawrence Erlbaum Associates.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). Student-generated questions: a meaningful aspect of learning in science. *International Journal of Science Education, 24*, 521–549.

Chiu, C.-H., Wu, C.-Y., & Cheng, H. W. (2013). Integrating reviewing strategies into shared electronic note-taking: questioning, summarizing and note reading. *Computers & Education, 67*, 229–238.

Corpus, A. (2013). *Test construction manual*. Retrieved May 17, 2015 from https://portal.utpa.edu/utpa_main/daa_home/ogs_home/ogs_imagesfiles/Test%20Construction%20Manual_Corpuz.pdf.

Devine, M., & Yaghlian, N. (2015). *Test construction manual: construction of objective tests*. Retrieved May 17, 2015 from http://www.cte.cornell.edu/documents/Test%20Construction%20Manual.pdf.

Dori, Y. J., & Herscovitz, O. (1999). Question-posing capability as an alternative evaluation method: analysis of an environmental case study. *Journal of Research in Science Teaching, 36*(4), 411–430.

English, L. D. (1997). Promoting a problem-posing classroom. *Teaching Children Mathematics, 4*(3), 172–179.

Ge, X., & Land, S. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Research Technology and Development, 52*(2), 1042–1629.

Hannafin, M. J., Land, S., & Oliver, K. (1999). Open learning environments: foundations, methods, and models. In C. Reigeluth (Ed.), *Instructional-design theories and models* (Vol. 2, pp. 115–140). Mahwah, NJ: Erlbaum.

Hoeft, R., Jentsch, F., Harper, M., Evans, A., Bowers, C., & Salas, E. (2003). TPL-KATS—concept map: a computerized knowledge assessment tool. *Computers in Human Behavior, 19*(6), 653–657.

Hoffman, S. (1997). Elaboration theory and hypermedia: Is there a link? *Educational Technology, 37*(1), 57–64.

Jackson, S. L., Krajcik, J. S., & Soloway, E. (1998). The design of guided learner-adaptable scaffolding in interactive learning environments. In C.-M. Karat, A. Lund, J. Coutaz, & J. Karat (Eds.), *Proceedings of ACM chi '98 human factors in computer systems*. New York, NY: Association for Computing Machinery.

Kojima, K., & Miwa, K. (2008). A system that facilitates diverse thinking in problem posing. *International Journal of Artificial Intelligence in Education, 18*(3), 209–236.

Lee, Y. S., Jang, Y., & Kang, M. (2015). Validity and responsiveness of concept map assessment scores in physical education. *The Physical Educator, 72*, 206–223.

Maki, R. H. (1998). Test prediction over text material. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 117–144). New Jersey: Erlbaum.

Mayer, R. (2010). *Multimedia learning*. New York: Cambridge University Press.

McClure, J., Sonak, B., & Suen, H. (1999). Concept map assessment of classroom learning: reliability, validity, and logistical practicality. *Journal of Research in Science Teaching, 36*, 475–492.

Mohammad, R. (2011). Use of syntactic elaboration techniques to enhance comprehensibility of EST texts. *English Language Teaching, 4*(1), 11–17.

Moses, B. M., Bjork, E., & Goldenberg, E. P. (1993). Beyond problem solving: problem posing. In S. I. Brown, & M. I. Walter (Eds.), *Problem posing: Reflections and applications* (pp. 178–188). Hillsdale, NJ: Lawrence Erlbaum Associates.

Nardone, C. F., & Lee, R. G. (2011). Critical inquiry across the disciplines: strategies for student-generated problem posing. *College Teaching, 59*(1), 13–22.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

Oh, S.-Y. (2001). Two types of input modification and EFL Reading comprehension: simplification versus elaboration. *TESOL Quarterly, 35*(1), 69–97.

Perez, J. A. (1985). *Effects of student-generated problems on problem solving performance. Unpublished doctoral dissertation*. New York, NY: Teachers College, Columbia University.

Pressley, M., Ghatala, E. S., Woloshyn, V., & Pirie, J. (1990). Sometimes adults miss the main ideas and do not realize it: confidence in responses to short-answer and multiple choice comprehension questions. *Reading Research Quarterly, 25*(3), 232–249.

Pressley, M., McDaniel, M. A., Turnure, J. E., Wood, E., & Ahmad, M. (1987). Generation and precision of elaboration: effects on intentional and incidental learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*(2), 291–300.

Reigeluth, C. M. (1983). *Instructional-design theories and models*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. (1992). Elaborating the elaboration theory. *Educational Technology Research & Development, 43*(3), 80–86.

Reigeluth, C. M. (1999). The elaboration theory: guidance for scope and sequence decisions. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. II). Hillsdale, NJ: Lawrence Erlbaum Association.

Reiska, P., Cañas, A. J., Novak, J. D., & Miller, N. L. (2008). *Concept mapping for meaningful learning and assessment: The need for a paradigm shift in science education for post-soviet societies* (pp. 128–142). Frankfurt: Peter Lang Company.

Rice, D. C., Ryan, J. M., & Samson, S. M. (1998). Using concept maps to assess student learning in the science classroom: must different methods compete? *Journal of Research in Science Teaching, 35*, 1103–1127.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: a review of the intervention studies. *Review of Educational Research, 66*(2), 181–221.

Seifert, T. L. (1994). Enhancing memory for main ideas using elaborative interrogation. *Contemporary Educational Psychology, 19*(3), 360–366.

Shadish, W. R., & Luellen, J. K. (2006). Quasi-experimental design. In J. Green, G. Camilli, & P. B. Elmore (Eds.), *Handbook of complementary methods in education* (pp. 539–550). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Silver, E. A., & Cai, J. (1996). An analysis of arithmetic problem posing by middle school students. *Journal for Research in Mathematics Education, 27*(5), 521–539.

Smith, P., & Savenye, W. (1991). *Course packet* (pp. 140–144).

Sternberg, R. J. (1997). *Thinking styles*. New York: Cambridge University Press.

Stoyanova, E., & Ellerton, N. F. (1996). *A framework for research into students' problem posing in school mathematics*. Proceedings of the 19th annual conference of the mathematics education research group of australasia (MERGA), June 30-July 3, 1996 at the University of Melbourne.

Vreman-de Olde, C., & de Jong, T. (2004). Student-generated assignments about electrical circuits in a computer simulation. *International Journal of Science Education, 26*(7), 859–873.

Walker, J. M. T., & King, P. H. (2003). Concept mapping as a form of student assessment and instruction in the domain of bioengineering. *Journal of Engineering Education, 19*(2), 167–179.

West, D. C., Pomeroy, J. R., Park, J. K., Gerstenberger, E. A., & Sandoval, J. H. (2000). Critical thinking in graduate medical education: a role for concept mapping assessment? *Journal of the American Medical Association, 284*, 1105–1110.

Wittrock, M. C. (1978). The cognitive movement in instruction. *Educational Psychology, 13*, 15–29.

Yu, F. Y. (2005). *Promoting metacognitive strategy development through online question-generation instructional approach*. Proceedings of International conference on Computers in education 2005, pp. 564–571. Nov. 28-Dec. 2. Singapore: Nanyang Technological University.

Yu, F. Y. (2009). Scaffolding student-generated questions: design and development of a customizable online learning system. *Computers in Human Behavior, 25*(5), 1129–1138.

Yu, F. Y. (2012). *Learner-centered pedagogy + adaptable and scaffolded learning space design—online student question-generation*. Keynote speech delivered at International conference on Computers in education 2012, November 26-30, Singapore.

Yu, F. Y. (2013). Preliminary assessment of online student-generated tests for learning. In S. C. Tan, Y. T. Wu, T. W. Apko, L.-H. Wong, C.-C. Liu, T. Hirashima, et al. (Eds.), *Workshop proceedings of the 21st International conference on Computers in education 2013* (pp. 183–186). Bali, Indonesia, November 18-22, 2013.

Yu, F. Y., & Chen, Y. J. (2014). Effects of student-generated questions as the source of online drill-and-practice on learning. *British Journal of Educational Technology, 45*(2), 316–329.

Yu, F. Y., & Hung, C.-C. (2006). *An empirical analysis of online multiple-choice question-generation learning activity for the enhancement of students' cognitive strategy development while learning science. Lecture series on computer and computational Sciences: recent progress in computational sciences and Engineering*. Selected papers from the International conference on Computational methods in sciences and engineering (ICCMSE2006), pp. 585–588, October 27-November 1, 2006, Chania, Crete, Greece.

Yu, F. Y., & Li, M.-H. (2011). *Effects of different types of online student question-generation on learning*. Proceedings of International conference on Computers in education 2011 (pp. 768–770), (Chiang Mai, Thailand).

Yu, F. Y., & Liu, Y. H. (2005). Potential values of incorporating multiple-choice question-construction for physics experimentation instruction. *International Journal of Science Education, 27*(11), 1319–1335.

Yu, F. Y., & Liu, Y. H. (2008). The comparative effects of student question-posing and question-answering strategies on promoting college students' academic achievement, cognitive and metacognitive strategies use. *Journal of Education & Psychology, 31*(3), 25–52.

Yu, F. Y., & Su, C.-L. (2013a). The design, development and preliminary evaluation of an online student-generated tests learning system. In L.-H. Wong, C.-C. Liu, T. Hirashima, P. Sumedi, & M. Lukman (Eds.), *The main proceedings of the 21st International conference on Computers in education* (pp. 375–378). Bali, Indonesia, November 18-22, 2013.

Yu, F. Y., & Su, C.-L. (2013b). *The construction and use analysis of student-constructed tests online learning system*. Taiwan academic Network conference 2013. Taichung, Taiwan: National Chung Hsing University. October 23–25.

Yu, F. Y., & Wu, C. P. (2013). Predictive effects of online peer feedback types on performance quality. *Educational Technology and Society, 16*(1), 332–341.

Yu, F. Y., & Wu, C. P. (2012). Student question-generation: the learning processes involved and their relationships with students' perceived value. *Journal of Research in Education Sciences, 57*(4), 135–162.

Yu, F. Y., Wu, C. P., & Hung, C.-C. (2014). Are there any joint effects of online student question generation and cooperative learning? *The Asia-Pacific Education Researcher, 23*(3), 367–378.