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Development of a Similar-question Generator to Support Peer Teaching

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We developed a similar-question generator that can produce a set of similar questions based on the content of an extensible markup language description file, including definitions of variables and a calculation formula for correct or incorrect answers and choices. For the evaluation of the generator, we installed it in our learning management system (LMS) and used the LMS in three general chemistry classes. The results of the recorded data compared with data from the control group showed that the exercise using similar questions among students activated more peer teaching than the exercise that offered identical questions for all students. With regard to term examinations, the scores for the questions in exercises that posed similar questions significantly increased compared with the scores for the questions in exercises that posed identical questions. Finally, according to the results of a questionnaire survey, the exercise offering similar questions was viewed favorably by 82% of respondents, especially those in the middle and low achieving students.

Keywords: question generation, similar questions, peer teaching, chemical education, learning management system

Introduction

Peer teaching is a complex process by which students learn from other students who are more experienced and knowledgeable about the subject material. In peer teaching, students work in the zone of proximal development (ZPD) proposed by Lev Vygotsky in a 1978 article. Vygotsky defined the ZPD as “the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." When students assist each other in working within this zone during their collaborative interactions, they can perform at levels that they could not on their own.

Vasay (2010) studied the effect of peer teaching in college mathematics and concluded that "Peer teaching greatly affects the intellectual and moral values of the students, such as the ability to express their ideas, mastery of different concepts, time management, sense of responsibility, sharing, self-discipline, self-reliance, self-confidence, resourcefulness, cooperation, obedience, etc." Peer teaching was also applied as a methodology in teaching chemistry. Gosser and Roth (1998) found statistically significant improvement by a peer-led team learning as measured by grades, retention, and levels of student satisfaction. Tien et al. (2004) reported that "interacting with other students and explaining their reasoning to one another had a much greater effect on their understanding." In our case, we did not incorporate peer teaching into our course intentionally but we found that exercises using similar questions effectively activated peer teaching.

We have used homemade LMS in face-to-face general chemistry classes at Tokai University, Kanagawa, Japan, since 2001. In these classes, we introduced quiz-based exercises to enhance encoding and verification based on Gagne's nine events of instruction (Gagne, Wager, Golas, & Keller, 2005). However, these quiz-based practices were not sufficiently effective for low achieving students because identical questions were distributed to all students, who then copied the answers from high achieving student. To solve this problem, first, we distributed different questions to each student. This strategy worked to prevent copying but it led low achieving students to giving up taking quizzes by themselves and instead to frequently ask for help from upper achieving students. Next, we prepared similar questions, in which variables, figures, and choices varied slightly, and manually distributed them in a class. As a result, the one-way asking behavior was reduced, and peer teaching among low achieving students was activated.
Although the quiz-based exercises containing similar questions are expected to be effective, it is difficult to conduct these exercises because they require many similar questions. Our next step was to develop a similar-question generator to improve efficiency in preparing similar questions and incorporated it in classroom practice to validate its usefulness.

Research Question

The purpose of this study was to develop a similar-question generator as an LMS module and to evaluate how quiz-based exercises using this LMS influence peer teaching. One of the important ways to conduct the exercise effectively is to prepare a large number of similar questions. For this reason, first, we developed the module and installed it in our homemade LMS.

Methodology

Development of a Similar-Question–Generation Module

Several quizzes have been developed in chemistry education by research teams (Kolodny & Bayly, 1983; Freasier, Collins, & Newitt, 2003). In these studies, questions were stored in the database beforehand and randomly displayed in a runtime environment. This methodology makes it difficult to prepare a large number of questions because the teacher has to do so manually, consuming much time and labor. While Takano and Hashimoto (2004) and Kanenishi et al. (2003) reported methods for generating questions, these methods used a specialized knowledge base; as a result, it was too difficult for non-experts to describe the knowledge embedded in the question. In our LMS, each question is defined using extensible markup language (XML) and is delivered to each student personal computer (PC); the similar-question generator was developed in JavaScript and PHP. Hence, our module generates similar questions dynamically on the client side.

First, we checked the types of questions that were defined as quiz modules of some LMSs and then checked and classified questions in the former contents of chemistry courses developed for freshman students. Then, we defined generation types and answer types based on frequency. Details of these types are shown in Table 1. A question is defined as a combination of the generation type and the answer type.

Table 1. Generation Types and Answer Type Adopted by the Generator

Category	Type Name	Description
Generation	Select	The generator selects items from lists or range of values.
	Calculate	Items are calculated from defined variables.
Answer	Short answer	A student answers the question using a word or phrase.
	Multiple choice	A student chooses from multiple selected/calculated items.

Screenshots of the generated questions are shown in Figure 1. The generator can produce many similar questions; we show two examples herein. Students observe the differences among questions and may also notice that the differences are not extensive. Figure 2 shows the corresponding XML code that can generate variations of similar questions.

For structuring a definition, we defined the elements ask, answer, and explanation. The question statement and variables are defined in the ask element. In the answer element, the answer types are defined. A feedback statement is defined in the explanation element.

Additionally, we defined the block and blocks elements to raise the flexibility of the definition. By adopting these elements, we can embed them in the structures of questions.

Generated items from the variable can be used in the answer and explanation elements. If one wants to use generated numerical values in calculations, one need only define numerical expressions with the names of variables. The expression was interpreted by the handmade morphological analysis parser that supported arithmetic operations.

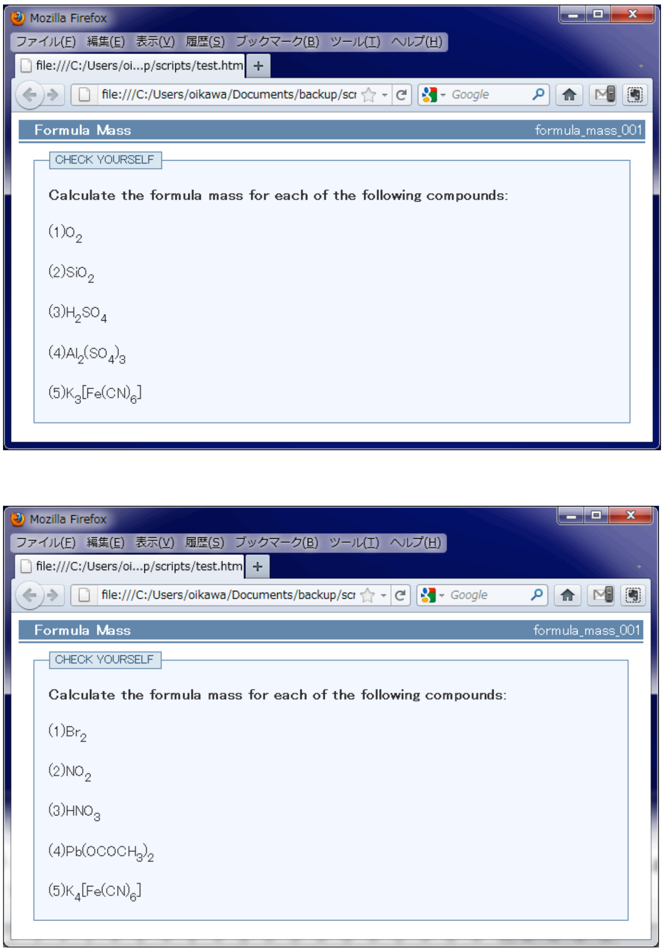

Figure 1. *Examples of generated similar questions. These two questions were produced from a single definition file coded by extensible markup language (XML). The chemical formulas are randomly selected and arranged from proposed items in the XML file.*

The schematic diagram of the exercise, with similar questions used in our homemade LMS, is shown in Figure 3. The generator was coded in JavaScript and PHP.

The LMS sends the generation module and a question-definition file to each client PC according to the content of a personalized course definition file. Each student who has access to the quiz can be logged in using the primary LMS function.

```
<?xml version="1.0" encoding="UTF-8"?>
<question check="off">
<caption>Formula Mass</caption>
<ask><b>Calculate the formula mass for each of the following compounds:</b></ask>
<blocks>
  <block><ask>(1)H<SUB>2</SUB></ask></block><block><ask>(1)O<SUB>2</SUB></ask></block>
  <block><ask>(1)N<SUB>2</SUB></ask></block><block><ask>(1)Cl<SUB>2</SUB></ask></block>
  <block><ask>(1)Br<SUB>2</SUB></ask></block>
</blocks>
<blocks>
  <block><ask>(2)SO<SUB>2</SUB></ask></block><block><ask>(2)SiO<SUB>2</SUB></ask></block>
  <block><ask>(2)CO<SUB>2</SUB></ask></block><block><ask>(2)NO<SUB>2</SUB></ask></block>
</blocks>
<blocks>
  <block><ask>(3)HNO<SUB>3</SUB></ask><block>…</block>
</blocks>
<blocks>
  <block><ask>(4)Ca(NO<SUB>3</SUB>)<SUB>2</SUB></ask></block><block>…</block>
</blocks>
<blocks>
  <block><ask>(5)K<SUB>4</SUB>[Fe(CN)<SUB>6</SUB>]</ask></block><block>…</block>
</blocks>
</question>
```

Figure 2. *The corresponding extensible markup language (XML) code for Figure 1. The generation module selects an item from each blocks tab. This means that teachers prepare sub-questions in only one file.*

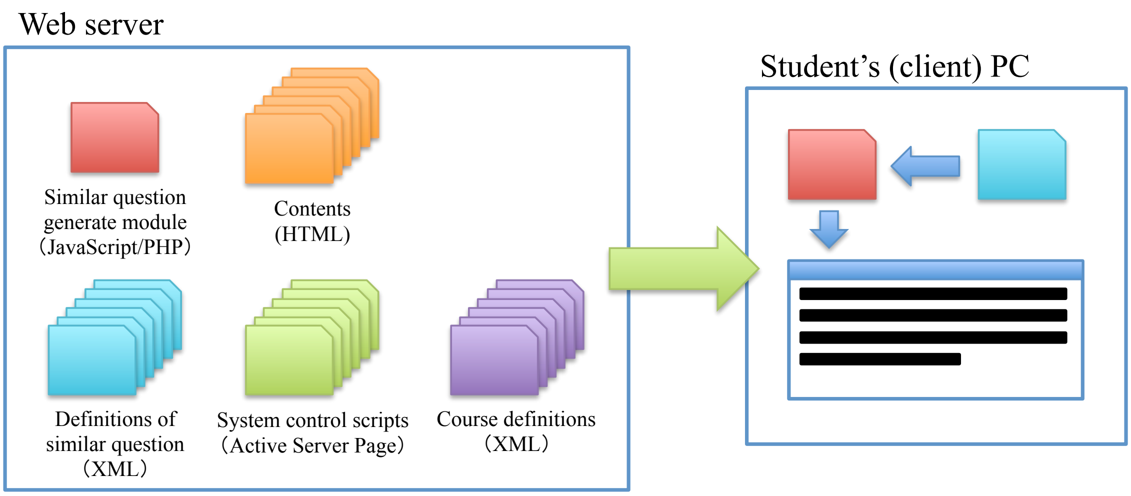

Figure 3. *Schematic diagram of the protocol used to deliver the similar questions to each client personal computer (PC). When a student accesses the Web server using a browser, the generation module (red folder icon) and a question definition (blue folder icon) are downloaded onto the student's PC. After that, the module produces similar questions according to the question definition at run time. HTML indicates hypertext markup language; XML, extensible markup language.*

To test the generator, we prepared approximately 20 question-definition files and then generated and printed out all variations of similar questions from these files via the generator. After checking these printed questions, we debugged the generator and installed it in the LMS that we have used in our lectures. During operation testing, we experienced no problems.

To validate the generator, we replaced some questions from former chemistry-course contents in the generator and used the new questions in the actual course. Students in these lectures wrote down the location of their PC, the phrasing of questions, and their answers.

Classroom Practice

To evaluate the exercise with similar questions, we applied the developed system in three general chemistry classes. These classes are remedial courses designed for students who had hardly been exposed to chemistry during high school. Each semester, there are 40 or fewer students per class. Classes meet for 90 minutes twice weekly in a computer center, in which each student sits in front of a PC.

In each class, first, the teacher briefly explained the topics; then, students read texts and worked on exercises in the LMS, in which they each received a different set of similar questions generated by the developed module. Students were permitted not only to talk each other but also to walk about the classroom and to discuss their questions with each other. We expected that peer teaching would be activated as a result. Finally, students submitted their paper answer sheets to the teacher. The conditions for the classes are shown in Table 2.

Table 2. *Condition of General Chemistry Classes Used to Evaluate Peer Teaching Effects in Exercises Using Similar Questions*

Group	n	Year	Majors of Students, n.	Grade Level(s) of Students
A	29	2011	1	Sophomore
B	24	2011	3, mixed	Sophomore, Junior, Senior
C	14	2012	3, mixed	Senior
D	39	2010	1	Sophomore

Recording Student Activity

Based on the results of classroom practice, we expected that the exercise containing similar questions would more strongly activate peer teaching, which might affect student activities. We took written notes on the activity or recorded it using digital video. The recorded data was converted into a relationship diagram in which pictures of the students were linked together by arrows, from the teacher role student to the student-learner role.

Questionnaire Survey

At the end of the semester, we administered a questionnaire-based survey to determine students' attitudes about peer teaching, as shown in Table 3. This survey was conducted with groups that had used the exercise containing similar questions.

Table 3. *Statements and Types of Questions in the Questionnaire*

Statement	Type
Did you learn from or teach somebody the answers or how to solve problems?	Dichotomous: Yes/No
What was your main role in peer teaching?	Bipolar: Teacher→Learner
Was peer teaching helpful or unhelpful in your learning?	Bipolar: Helpful→Unhelpful
Did your partner's understanding (assisted by your teaching) increase or decrease your satisfaction?	Bipolar: Increase→Decrease
Did you participate in peer teaching? If not, why?	Closed and open formats
Did you teach other students? If so, how did you feel when your partner solved the question with your assistance?	Closed and open formats
Which feeling(s) do you have when teaching other students? (choices are omitted)	Closed and open formats
Which feeling(s) do you have when learning from other students? (choices are omitted)	Closed and open formats

Analysis of Percentage of Correct Answers

Tessier (2007) reported that students in an introductory biology class performed better on exam questions based on material that they had taught to peers or had learned from peers than on material they had learned from a traditional lecture approach. This study showed that the usefulness of a certain method for peer teaching could be evaluated by analyzing the results of the examination. We classified each exam's questions into two categories: questions based on the exercise with similar questions and questions based on the exercise with identical questions; we then compared the rate of correct answers among the categories.

Results

A pre-test was conducted in the first meeting of each class for evaluation of the group's level of achievement. The pre-test was composed of 30 basic questions about information that students would normally learn in high school in Japan. Result of t testing for the pre-test showed no significant differences between each group.

The s Student Activity

A typical relationship diagram is shown in Figure 4, in which arrows show question-asking behaviors (marked based on teacher role or learner role of students). In the case of the exercise containing identical questions (Figure 4, part a), the role of peer teaching seemed almost fixed because virtually always, higher achieving students performed the teacher role and lower achieving students performed the learner role. The targets of question asking were concentrated on specific students. Additionally, the group members were only provided with the answers to learners' questions; they were not told how they could solve the questions. Critical examination of students' answer sheets showed that mistakes made by higher achieving students were spread to the rest of the class.

In contrast, in Figure 4, part b, in which the exercise used similar questions, simple asking behaviors were largely dispersed. One of the notable points of this case is that the number of arrows indicating the teacher and learner roles increased compared with the case detailed in part a. This means that many students played the role of teacher and that peer teaching was activated qualitatively. The act of teaching others enhances students' own learning (Bargh & Schul, 1980; Whitman, 1988). Therefore, peer teaching, including exercises containing similar questions, is a useful learning methodology.

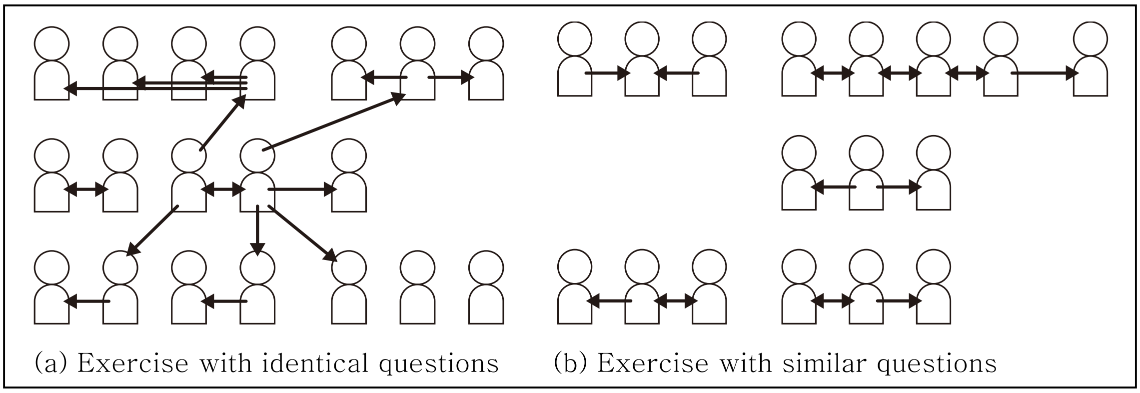

Figure 4. *Typical-relationship diagrams. These diagrams show patterns of student activities. An arrow is drawn from the teacher-role student to the learner-role student based on recorded data from an in-class activity. A two-way arrow indicates that students taught each other; in other words, peer teaching occurred among those students.*

Questionnaire Survey Results

We conducted a questionnaire survey in groups A and B. The response rate was 74% (39 of 53 students); 32 of 39 respondents (82%) reported that they had participated in peer teaching (Table 1). Our results also showed that students who did not participate in peer teaching believed it to be difficult to ask questions of their peers in other majors or grade levels. Additionally, analysis of the relationship diagram showed that peer teaching occurred locally in group B, which consisted of mixed majors, whereas peer teaching spread widely in group A, which consisted of students of the same major and grade level (Table 1). These results suggest that students' sense of familiarity with other students affects the occurrence of peer teaching. This idea is supported by the fact that less peer teaching appeared in group C, in which student relationships were weak. However, the results of the questionnaire survey showed that students who did not participate in peer teaching wished to learn in partnership with other students. Pairing of students is an important factor to support learners in an e-learning environment (Monobe, Tanaka, & Torigata, 2008); it is necessary for future research to study pairing methods as a means of further activation of peer teaching.

The influence of the primary role of students in aiding one another's learning and satisfaction with the learning process is shown in Table 4 and Table 5. These results show that peer teaching is helpful to student learning and helps to increase satisfaction with the learning process; this is especially true of middle achieving students. Generation of satisfaction is an important strategy in the Attention, Relevance, Competence, and Satisfaction (ARCS) Model approach (Keller, 2010). We believe that our methodology, which uses similar questions, can be applied to motivation.

Table 4. *Cross-tabulation of the Main Role of the Student and the Helpfulness of Peer Teaching (Group A and Group B)*

	"Was peer teaching helpful or unhelpful in your learning?"				
Main Role	5 (Helpful)	4	3	2	1 (Unhelpful)
5 (as Teacher)	0	1	0	0	0
4	4	3	0	0	0
3	6	4	2	0	0
2	1	1	4	0	0
1 (as Learner)	0	0	0	0	0

Table 5. *Cross-tabulation of the Main Role of the Student and Change in Level of Satisfaction (Group A and Group B)*

	"Did your partner's understanding (assisted by your teaching) increase or decrease your satisfaction?"				
Main Role	5 (Increased)	4	3	2	1 (Decreased)
5 (as Teacher)	0	0	1	0	0
4	2	3	2	0	0
3	4	6	2	0	0
2	1	1	4	0	0
1 (as Learner)	0	0	0	0	0

Exam Score

Previous studies have shown, by analyzing test scores, that peer teaching affected the achievement level or grades of students (Tessier, 2007; Giuliodori, Lujan, & DiCarlo, 2008). If exercises with similar questions activate peer teaching, they should also affect test scores.

We compared the percentage of correct answers to each of the questions in the 2011 exam with those of the 2010 exam (Table 5). The total number of questions was 70; identical questions were used in both exams. Students from groups A and B took the 2011 exam, and students from group D took the 2010 exam. Chi-square test revealed a significant difference ($\chi 2(1) = 4.226$, $P < .05$) between question types and the changing percentage of correct answers. This means that the exam score analysis also supported the assertion that peer teaching affects exam scores when students use our exercise, which poses similar questions.

However, no significant difference was observed between question types and the changing percentages of correct answers in the 2012 exam taken by group C. In that group, most students learned individually; the occurrence of peer teaching was the lowest among the three groups (Table 6).

Table 6. *Number of Questions in 2011 Exam (Group A and Group B, Similar Questions and Identical Questions) For Which Percentage of Correct Answers Increased or Decreased Compared With 2010 Exam (Group D, Only Identical Questions)*

Question Type	Increased	Decreased
Exam questions related to the exercise using identical questions	21	31
Exam questions related to the exercise using similar questions	13	5

Conclusion

We found that exercises using similar questions that had been created by our similar-question generator activated peer teaching effectively in face-to-face general chemistry classes. When students undertook the exercise with identical questions, the roles of students were practically fixed, with higher achieving students as teachers and lower achieving students as learners. In contrast, in the exercise with similar questions, many students played the roles of teacher and learner; hence, peer teaching was activated qualitatively.

The results of the questionnaire survey showed that 82% of respondents reported that they had participated in peer teaching and that the peer teaching was helpful and had increased their satisfaction level; this was especially true of middle achieving . Analyzing the questionnaire results and the relationship diagram indicated that students' sense of familiarity with other students affects the occurrence of peer teaching; this suggested the importance of the pairing methods used. When we compared the percentage of correct answers to each of the questions in the 2011 exam with those from the 2010 exam, the results supported the assertion that peer teaching affects exam scores.

For greater activation of peer teaching, it is necessary for all students to become more capable peers. The use of similar questions prompted students to act as such peers. Hence, we must provide different variations of similar questions to each student as often as possible. The similar-question generator in this study can only generate a variation of similar questions at random, so if a definition of a similar question is too simple, an identical version is provided to many students. As a result, collaborative interaction rarely occurs. To avoid this situation, we must prepare more complex definitions or improve our methods of providing similar questions. The generator is optimized for the generation of questions for our chemistry course. If we apply the generator to other fields, we will likely have to add other functions to the generator.

The evidence of activation of peer teaching in this study was based on an overview of recorded data. These data did not show us how students behaved in each interaction. Hence, for a more thorough study, each interaction will need to be recorded.

Our morphological analysis parser only supports arithmetic operations. Developing a higher morphological analysis parser or using a library of morphological analysis is necessary to do more complicated numerical formulas.

Regarding the class design in this study, only peer instruction was considered. The addition of novel ideas to the orientation of the similar-question generator and instruction by the professor will make the class design more sophisticated.

Because similar questions were displayed on the monitor of the desktop PCs, the occurrence of peer interaction was limited among adjacent students. Adjustment of the generator so that it can be used with smartphones and other such devices will be a future tactic to foster improvement in peer activities, because it will allow students to examine similar questions together.

In future works, we will continue to report on our development of the similar-question generator and its use in classroom practices. We are developing a Moodle version of this module, which will be open in the near future.

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