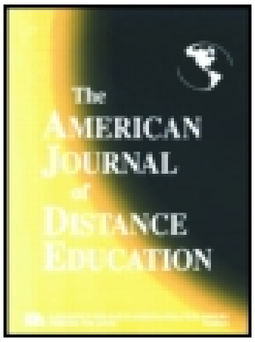

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A Question-Collaboration Approach to Web-Based Learning

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A Question-Collaboration Approach to Web-Based Learning

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A Web-based tool that allows students to generate multiple-choice questions in a collaborative, distributed setting was evaluated through several comparisons. Students first completed a Web-based tutorial on writing effective multiple-choice questions and then authored questions on a given topic. Next, using the Web-based tool, groups of students reviewed and critiqued questions written by others within their group on the same topic. Based on these critiques, students were permitted to modify their original questions. They then were tested on questions prepared by other groups, either on the same or on other topics. Students who collaborated within a topic scored approximately 7% higher on the test within that topic than students who either collaborated on other topics or did not use the collaboration tool. Of the 336 questions developed, 77% were considered acceptable by instructors, indicating that the questions could be repurposed for inclusion in future tests. A majority of the critiques were constructive, indicating that the collaborative process was supportive of learning.

Whether in a traditional classroom setting or through distributed learning technologies, learning is clearly influenced by interactions among learners. Further, the quality of interactions influences the extent and depth of learn-

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ing (Shute, Lajoie, and Gluck 2000). Moore (1989) defines three types of interactions in instructional settings: learner–instructor, learner–content, and learner–learner. Each promotes learning, but in classroom environments, the emphasis is traditionally on learner–instructor and learner–content interactions, as knowledge is seen traditionally as flowing toward the learner. Social constructivist theories of learning, however, point to learner–learner interaction as a key to enhancing learning. A challenge for instructional developers and designers of distributed learning environments, then, is how to support such learning.

Wagner (1997) defines interactions as reciprocal events requiring two objects and two actions. Such interactions foster behaviors in which individuals and groups influence one another. For example, the nature of learner–learner interaction through the use of text messaging in Web-based environments was demonstrated by Kang (1998), in which 85% of text messaging during a graduate-level course was among learners. The students felt that the use of text messaging allowed relationships to develop and social bonds among students to improve. Similar findings reported by Savery (1998) indicated that learning was promoted through online collaborative writing.

Wagner (1997) identifies thirteen types of interactions that can occur in distributed learning environments. Examples include interactions to increase willingness to engage in learning, to increase participation, and to enhance elaboration and retention. A feature of effective interactions is that they must result in the transfer of knowledge or a change in intrinsic motivation. Posing a sincere question and promptly receiving a correct reply is a fundamental example. The current research examines collaboration on writing questions as a type of leaner–learner interaction designed to enhance learning.

Question Generation as a Form of Learning

The study of question generation and question-based learning (QBL) has focused on the asking of sincere information seeking (SIS) questions (Graesser, Person, and Huber 1992). With SIS questions, the questioner does not know the answer but assumes that the person being asked will provide an answer. In such a scenario, the obvious result of asking questions is receiving answers. The process of learning, however, does not end with the answer to a question. When a questioner receives a useful answer, he or she is more likely to ask follow-on questions, leading to the development of an inquiring learning environment (Minstrell 1999). The asking and answer-ing of questions, therefore, builds upon itself, producing common ground among participants.

The process of producing a SIS question requires active processing of information, leading to more in-depth learning (Graesser and Wisher 2001). To develop a question, several metacognitive tasks must be completed. The questioner must first determine what he or she does not know and then must construct a question that relates this uncertainty to others. This increased metacognitive demand may be why some people have difficulty generating good questions, even when they understand the topic (Miyake and Norman 1979; Otero and Graesser 2001).

The questions asked by a person about a particular topic allow others to assess the questioner's level of understanding (Swartz 1987). For example, a person must have at least some knowledge about a topic in order to ask in-depth questions. In addition, the questions identify content areas where the questioner has incomplete information. Questions, therefore, indicate what a person both knows and does not know.

The majority of research regarding question asking has focused on the asking of questions in a face-to-face setting (Graesser and Wisher 2001), although some studies assessed question asking in a Web-based setting. One such study (Blanchette 2001) found that questions are developed differently in a face-to-face setting than in an online learning environment. In online environments, the questions are at higher cognitive levels than in face-to-face settings, due probably to the extra time to ponder and edit the questions.

Online Collaboration

The American Psychological Association (1997), as reflected in its "Learner-Centered Psychological Principles," acknowledged the importance of social interactions in a learning environment. These principles stress the importance of learners collaborating in the course of constructing knowledge. Through collaborative tasks such as discussing, summarizing, clarifying, and integrating course content into an overall framework, learners gain a deeper understanding of the content (Deatz and Campbell 2001). Collaborating with fellow learners allows for the synergistic construction of knowledge, so the strength of one team member can be shared with the other members who may possess complementary strengths. This form of collaboration, which applies social constructivist principles, leads to a productive learning environment (Palincsar 1998). Numerous studies have shown that the use of collaborative learning exercises leads to improved knowledge acquisition as compared to instruction without collaborative exercises (Alkhateeb and Jumaa 2002; Bonk and Wisher 2000; Moore 2001).

The effective use of collaboration is growing in Web-based instruction (Duffy and Kirkley 2004; Roberts 2004). Individuals in distance learning courses often feel isolated because of a lack of natural interaction with class members (Muilenburg and Berge 2001). Distance learners rarely have the opportunity to interact face-to-face as in a traditional classroom. Navarro and Shoemaker (2000) found that many distance learners sense that more learner–learner interaction should be designed into online courses to alleviate the feeling of isolation. Collaborative online tools, therefore, are needed to increase learner–learner interaction, which should subsequently motivate students in a distributed learning environment (Fisher and Coleman 2001–2002).

According to Garrison, Anderson, and Archer (2001), another important aspect of online collaboration is that it usually is structured to promote inquiry. Such structure includes defining problems or topics, trying multiple solutions, feedback, and reflecting on the process and outcome. Garrison, Anderson, and Archer found that with asynchronous text-based conferencing, most of the communication could be identified as exploration, the seeking of new information.

The value of collaborative question generation as a form of learner–learner interaction is examined here. The research integrates two related areas: (1) to identify the usefulness of question-based learning in dealing with course content, and (2) to assess the usefulness of collaboration during question-based learning.

Method

The effects of collaborative question writing on learner outcomes, such as test performance, quality of questions developed, interaction, and satisfaction, were assessed. The application used was TEAMThink™, produced by Athenium LLC, a Web-based collaboration tool where teams of distributed learners develop questions. Hereafter this application is referred to as the collaboration tool. (Note: The use of trademark or copyright material does not imply endorsement of a product by the U.S. Army Research Institute for the Behavioral and Social Sciences or by the U.S. Department of Defense.)

Participants

The participants were students at three Army schools: the Engineer School at Fort Leonard Wood, Missouri; the Ordnance Munitions and Electronic Maintenance School at Redstone Arsenal, Alabama; and the Intelligence School at Fort Huachuca, Arizona. To complete the research task, the participants needed between three and four hours across two sessions.

Essentially there were three separate issues investigated across the three groups. Participants at the Engineer School were used for a between-group assessment. In this comparison, 104 students were assigned to an experimental group that wrote questions and participated in the collaborative exercise and 108 students were assigned to a control group that wrote questions, but did not participate in the collaborative exercise. The purpose of this comparison was to see if collaborative QBL improved learning beyond individual QBL.

The forty participants from the Ordnance School were used in a within-group design, a comparison of how the participants performed on a test of the topic they completed with the collaboration tool versus their performance on a test of a topic of which they did not use the collaboration tool. The purpose was to compare performance between two course topics they had previously covered, one topic they used with the collaboration tool and another topic they did not use with the collaboration tool.

Fifty-five participants from the Intelligence School used the collaborative tool. Their results, along with the participants from the Engineer School and the Ordnance School, were used to assess additional aspects of the collaboration tool, such as the quality of questions generated and the types of comments produced during collaboration. For all groups, the collaborative activity was integrated into a course required for career advancement.

Apparatus

Each school provided a distributed learning classroom, equipped with computer workstations with high-speed Internet access. The collaboration tool, the tutorial, and all collaboration occurred over the Internet. Interactions and performance data were stored on a central server in Boston, Massachusetts. For experimental control, all participants used the collaboration tool online in a computer-equipped lab. When using the collaborative tool, each student was sitting at his or her own computer station and the instructor discouraged face-to-face interaction. All student collaboration was mediated through the Web-based collaboration tool.

Procedure

Participants in the control condition at the Engineer School were asked to construct questions based on the same topic as members of the experimental group. The control group then took a test consisting of those questions. The participants in the experimental group completed a tutorial, used the question collaboration tool, and then took a test of questions developed with the collaboration tool. All students who used the collaborative tool were sitting at individual computer stations and interacted only over the Web.

Tutorial. Participants first independently completed a Web-based, self-paced tutorial, instructing them on how to write effective multiple-choice questions. The tutorial, which required approximately forty-five minutes to complete, was divided into three modules: (a) learning through questions, (b) writing properly formatted questions, and (c) creating a set of answers that includes only one correct answer and three appropriate incorrect options, or distracters. During each module, appropriate examples of questions and answer sets were presented as models. The requirement was to cycle through a module until achieving a criterion score on the end-of-module quiz before continuing to the next module. The control group in the Engineer School did not view the question-writing tutorial. However, analyses (detailed later in this article) indicate that the quality of questions written by those in the control group was not significantly different than those in the experimental group.

Question collaboration. After completing the tutorial, participants were divided into teams, either through random assignment or based on preset groupings already established in the course, and were instructed to compose questions individually. The size of the teams varied from three to twenty-four members. The collaboration tool provided a template that included an area to write the question stem and separate areas to write the correct answer and distracters. An example of this template, including student comments, is illustrated in Figure 1. The template also had an area to offer the rationale for the question and an area where the question writer could list related reference material.

With the exception of the control group from the Engineer School, all teams were given specific course topics on which to generate their questions. In each location and in a specific class, half of the teams developed questions on one topic and the other half developed questions on a different

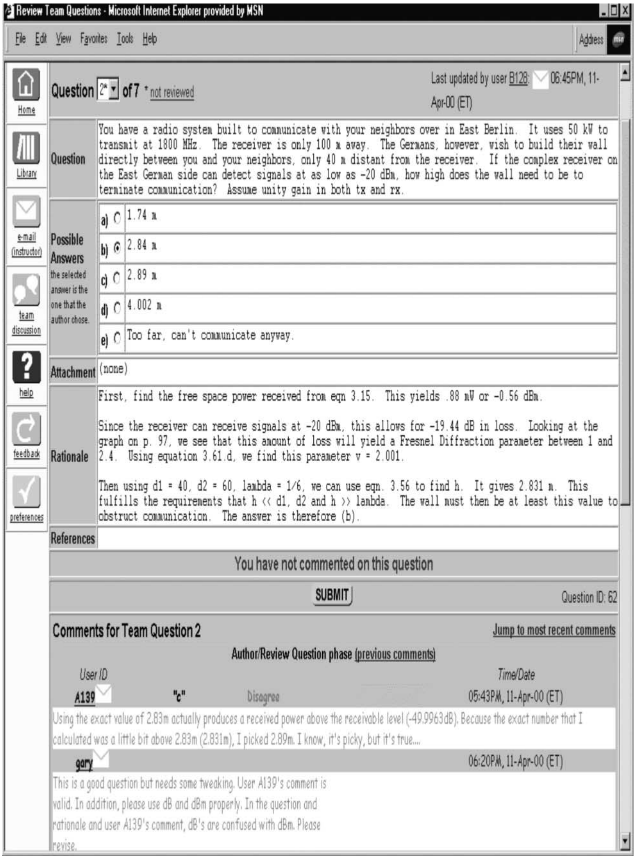

Figure 1. The Template for Writing Questions, Answer Stems, and Comments, Including a Student Example

topic. Ordnance School students were instructed to write three questions because they had smaller teams (3–6 members per team). In the other locations, students were put into larger teams (10–24 members per team) and were asked to write only one question each. As a general guideline for level of difficulty, students were asked to prepare questions that approximately 70% of the class could answer correctly.

Afterward, students critiqued questions written by their teammates on the same topic. For each question, the collaboration procedure was (1) answer the question; (2) see the proposed correct answer by the author; (3) provide a written critique, such as disagreeing with the author, rewording the question stem, and editing the distracters; and (4) comment on feedback from other teammates on the questions. When the students completed the review-and-commenting process, they were allowed to read the comments on their own questions and revise their original question as they felt necessary. Once the questions were in final form, the instructors reviewed them for technical and doctrinal accuracy as well as adherence to the course learning objectives. The Appendix provides two examples of instructor-accepted questions and comments to those example questions.

Test of questions. The final step of the collaboration process was for the participants to take a test of the questions developed by other teams on the same topic area, but which they had not yet seen. The questions that appeared on the tests were those that were accepted by the course instructors, so the number of items on each test varied across teams.

The participants from the Ordnance School took two tests. The first consisted of questions developed by other teams but on the same topic addressed during the collaborative process. The second test consisted of questions written by other teams, but from a different course topic. Both topics had been recently covered in the course. Comparing the scores from these tests allowed us to assess whether the collaboration process leads to higher scores within a topic.

Results and Discussion

Learning Effect

Two analyses were conducted to assess evidence for a learning effect. In the first analysis, the percentage of questions answered correctly during the test by the students in the control and experimental groups from the Engineer school were compared. In the second analysis, two sets of questions were used to assess the students from the Ordnance School; these included questions about the topic on which they collaborated (within topic) and a different topic that was also covered in class (across topic).

Engineer School. The percentage of questions answered correctly during the test was compared between the experimental and control groups. The experimental group participants answered 76.1% (SD = 10.4) of the questions correctly. The control group participants answered only 68.4% (*SD* = 10.6) of the questions correctly. The 7.7% difference between means was statistically significant (independent samples $t = 5.36$, $d.f. = 210$, $p < .01$). The effect size for this difference was 0.73 standard deviation units (difference between means of 7.7 divided by the pooled standard deviation of 10.5).

Ordnance School. In this group, students took two tests; the first used questions from the same topic addressed during the collaborative exercise (within) but composed by different teams; the second used questions from a different topic (across). In either case, students had not reviewed the questions beforehand. Participants averaged 7.3% higher scores on the "within" topic versus "across" topic tests (see Table 1), but the difference was not statistically significant (paired samples $t = 1.44$, $d.f. = 39$, $p = .159$). The effect size for this difference was 0.32 standard deviation units (difference between means of 7.3 divided by the pooled standard deviation of 23.0).

The collaboration during the question-generation exercise may have aided in the learning process, as reflected in the higher scores by the participants from the Engineer School who used the collaboration tool compared to the participants who wrote questions without collaborating. In the case of the Ordnance School when all scores were pooled, the difference between the "within" and "across" groups was not statistically significant, but did point in the same direction as the results from the Engineer School. The relatively high level of variability found from a small sample in the Ordnance School data may have led to the inconclusive finding between groups.

The results for the Engineer School and the Ordnance School both pointed in the same positive direction, but only the former was at a statistically significant level. This suggests that a learning effect, although not

Table 1. A Comparison of Scores of the Participants From the Five Ordnance School Groups That Participated in Two TEAMChallenges

	Group 1	Group 2	Group 3	Group 4	Group 5	ALL
Average within (%)	77.80	71.80	91.70	77.70	55.70	75.20
SD within (%)	24.60	24.60	9.80	25.20	11.20	24.70
Average across (%)	55.90	70.90	65.70	73.40	71.70	67.90
SD across (%)	15.70	23.70	13.40	22.90	10.50	21.10
Difference (%)	21.90	0.90	26.00	4.30	–16.00	7.30
N =	8	9	6	11	6	40
t =	2.46	0.06	2.70	0.51	–1.58	1.44
p =	.043*	.952	.021*	.622	.176	.159

$^*p < .05$.

consistently strong, was evident. The lack of effect strength may be due to the higher variability that occurred in the results from the Ordnance School relative to the Engineer School.

This research provides limited evidence that the use of a question-generation collaboration tool led to increased comprehension of the course content by students. Such findings provide additional support for programs that support collaborative learning (Alkhateeb and Jumaa 2002; Bonk and Wisher 2000; Fisher and Coleman 2001–2002) and question-based learning (Graesser, Person, and Huber 1992; Graesser and Wisher 2001). Deatz and Campbell (2001) proposed that learner control, performance feedback, and rehearsal of course content should all lead to increased comprehension. According to the "Learner-Centered Psychological Principles" proposed by the American Psychological Association (1997), collaborative social-constructive interactions, such as those that occurred during the collaborative exercise in this research, are an important component of the learning environment. The current research adds to previous research, which suggests that collaborative question-based learning can lead to higher quality instruction.

Additional Benefits of Collaborative QBL

Across all locations, 336 questions were written. The instructors accepted 258, or 77%, as technically correct and doctrinally accurate (see Table 2). Not only does such a collaboration tool improve learning, but the production of so many quality questions indicates that a collaboration tool could be used to generate a corpus of questions for later use by training developers, consequently reducing course development costs (Moore 2001). Furthermore, the collaboration tool calculates psychometric measures, such as percentage of individuals who answered each question correctly, providing a rank ordering of items. Such calculations would be helpful to a course planner considering computer adaptive testing.

Table 2. Number of Questions Authored, Instructor-Accepted Questions, and Percentage of Acceptable Questions Across All Locations

Location	Authored	Accepted	%
Engineer School	101	82	81
Ordnance School	180	135	75
Intelligence School	55	41	75
Total	336	258	77

The determination that most of the questions were doctrinally correct, demonstrating students' understanding of course content, was reassuring to the instructors. This finding is congruent with Swartz (1987), who stated that a question exposes the level of understanding by the questioner. Given that basic information on a topic is required to develop an effective question, instructors could use question generation to monitor student comprehension during courses. If most of the questions developed on a particular topic were acceptable, the instructor would know that the class in general has a clear understanding. If many of the questions were inaccurate or confusing, the instructor might consider reviewing the topic.

Comments to Questions

A total of 759 comments were made in response to the 336 questions, for an average of 2.3 comments per question. The comments made to the questions were categorized as constructive, correct/incorrect, value statement, unrelated, or trivial/nonsense. Constructive comments mentioned question content, answer content, and/or discussed how to improve the question. Correct/incorrect comments stated whether the question and answers were correct or incorrect without mentioning content. Value statement comments only stated either a positive or negative position toward the question (e.g., "good question"). Unrelated comments did not relate to the question content and provided no indication of the commenter's view of the question (e.g., "who wrote this question?"). Trivial/nonsense comments were not understandable (e.g., "xasgf"). Using a random sample of fifty-two comments, an interrater agreement score [agreements/observations] of 0.92 was obtained (Cohen's Kappa = 0.9).

A majority of comments (57%) were constructive, and an additional 6% and 17% fell under the correct/incorrect and value statement categories, respectively (see Table 3). Analysis of the comments indicates that 80% of comments provided at least some level of useful feedback regarding the question. The remaining 20% of the comments were either unrelated (18%) or trivial/nonsense (2%). There was no difference in both the frequency and the types of comments written among schools.

Most of the comments were constructive, which implies positive interaction among team members. The use of a collaborative question-generation program may be an effective means to promote learner–learner interaction, overcoming the isolated feeling that learners in distributed learning courses have reported (Alkhateeb and Jumaa 2002; Bonk and Wisher 2000).

Table 3. Number and Percentage of Each Category of Comment Written During the Question Authoring Phase, Test Phase, and Total for Both Phases

Category of Comments	Author Phase	%	Test Phase	%	Total	%
Constructive	228	56	202	57	430	57
Correct/Incorrect	20	5	25	7	45	6
Value Statement	79	19	53	15	132	17
Unrelated	76	19	63	18	139	18
Trivial/Nonsense	4	1	9	3	13	2
Sum	407	100	352	100	759	100

The mention of question content in most of the comments also indicates that the participants were thinking about the material when they wrote their comments. Such processing indicates active learning, which has been shown to improve comprehension and recall (Craik and Lockhart 1972; Deatz and Campbell 2001; Graesser and Wisher 2001). The writing of comments, therefore, may lead to greater understanding of the topic of a question.

Summary and Conclusion

The use of the collaborative question-generation tool produced positive outcomes for both students and instructors. The benefits to the students were an increased comprehension of the course material and a novel method of interacting with other students. These benefits were realized after only one use of the program; greater benefit would be expected if the collaboration tool were used repeatedly throughout a course. The benefits to the instructor were the development of quality questions with minimal time investment and the opportunity to monitor the topic comprehension by students.

The findings of the current research along with previous findings suggest that collaborative, question-generation exercises are effective learning tools. In the current research, students demonstrated an increase of approximately 7% in the questions they were able to correctly answer after using the collaborative question-generation program. The positive results of this research might be specific to the TEAMThink program, or may be generalized to collaboration and/or question-based learning in general.

The TEAMThink program was designed as a Web-based program so that it could be incorporated into either a distributed-learning or a traditional course. In either design, an instructor would receive, as a byproduct, a large number of questions, most of which could be easily repurposed during the course, or during subsequent iterations of the course. The development of these questions would help instructors save time in creating exams. An additional benefit to instructors is that through the implementation of a collaborative question-generation program, an instructor can gauge the level of comprehension by the students. The use of the collaboration tool across three different schools demonstrated that the program is not content-specific and can be used in various content areas.

Technologies that encourage interactions among learners are a vital ingredient for increasing the effectiveness of Web-based instruction. A recent meta-analysis of the limited literature on the effectiveness of Web-based instruction, in comparison to classroom instruction, indicated an average effect size of .24 (Olson and Wisher 2002). Evidence from research on advanced distributed learning technologies suggests that a greater degree of effectiveness is possible. For example, the personalized interactions that characterize intelligent tutoring systems lead to effect sizes on the order of a full standard deviation (Woolf and Regian 2000). By capitalizing on the natural advantages of quality learner–learner interactions, collaborations, and a learning environment that includes a question-generation strategy, the extent and depth of learning in Web-based instruction can substantially improve.

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Appendix
Examples of Questions and Comments From Two Locations

Engineer School

Question:
When developing a Scheme of Engineer Operations for use in the defense, which of the following criteria should you include for an obstacle group? (As per the question author, the correct answer is “d”)

(a) Task and Purpose
(b) Relative location and the maneuver unit it supports
(c) Indirect fires allocated to an obstacle group
(d) All of the above

Comments:

(1) Good Question
(2) Unsure if obstacles have task and purpose. Obstacles have intent, target, and location. Units have task and purpose not obstacles. Revise and rewrite.
(3) Task and purpose?????
(4) Good Question

Ordnance School

Question:
When transporting radioactive material, the proper label to affix to the package is based on what radiation level reading? (As per question author, correct answer is “a”)

(a) The radiation level at the surface of the container
(b) The radiation level of the materials being transported

(c) The radiation level of the carrier from 100ft away
(d) The radiation level inside the sealed carrier

Comments:

(1) Trick question, huh?
(2) Suggestion, to make your question clearer, perhaps you should re-word it to read, “When transporting radioactive material the proper label that is affixed to the package is based upon …”
(3) Could everyone with an answer please honestly tell me if they researched the question or came up with an educated guess?