Perceived Potential Value of Student Multiple-Choice Question-Construction in the Introductory Physics Laboratory

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***Abstract*—*The potential value of a multiple-choice question-construction instructional strategy for the support of students' learning of physics experiments was examined in the study. 42 university freshmen participated in the study for a whole semester. Analysis with one-group t-tests, using 3 as the expected mean, on quantitative summative data found that students' satisfaction toward past learning experience, and perceptions toward this strategy's potentials for promoting learning were statistically significant at the 0.0005 level while learning anxiety was not statistically significant. A constant comparison method adopted to categorize students' qualitative data further indicated that the influences of multiple-choice question-construction were evident in several significant ways, which worked together not only enhanced students' comprehension and retention of the obtained knowledge, but also helped distill a sense of empowerment and learning community within the participants. Based on the results yielded from past and the present study, it is suggested that multiple-choice question-construction is an instructional strategy with great potentials that physics instructors might want to consider for incorporating in their classrooms to help students become more active and intellectually engaged learners.*

Index Terms*—*Anxiety, Instructional strategy, multiple-choice question construction, Physics labs, Satisfaction,

INTRODUCTION

As far as instructional strategies per se, questioning is an essential educational tool for all disciplines in general and lies at the heart of scientific inquiry in particular [1]. Student generated-question has been suggested as a promising instructional strategy to facilitate students' cognitive elaboration and as a valuable alternative to achieving meaningful learning and reinforcing higher-order thinking skills [2]-[6]. Evidence from past studies generally supported teaching and the inclusion of the element of student questioning in instructional process for the enhancement of student text processing and reading comprehension, motivation, time-on-task, question-generation ability, creativity, problem-solving ability, and attitudes toward the subject matter studied [5]-[9]. Even though several studies showed the beneficial effects of student generated questions, the focus and context of existing studies exclusively evolved around how self-questioning may influence students' processing of prose or oral instruction. As more and more classrooms emphasize student-directed hands-on learning activities, the potentials of student generated question for the support of students' learning in such learning environment would warrant further investigation. Besides, past studies supporting the efficacy of self-questioning primarily involved posing open-ended questions or story problems. Analytically, relative to open-ended question-posing, which comprised of constructing a question and its answer/solution, when faced with the tasks of constructing multiple-choice questions, students would have the added cognitive task of pondering three distractors that can effectively discriminate those who have learned and mastered the concepts, principles, or procedures from those who have not. Seeing that the potentials of multiple-choice question-construction for the support of student-directed learning activity have yet been investigated, the main purpose of this study was to examine the potential values of its use in physics laboratory. Finally, there is evidence that students may show signs of hostility and resist changes in the classroom that requires them to handle more responsibilities [5]. As such, students' satisfaction and anxiety level associated with multiple-choice question-generation learning task would be an important aspect to be examined for future adoption and diffusion into the classroom. In summary, this study investigated students' perceived values of multiple-choice question-construction for physics experimentation learning as well as their satisfaction and anxiety associated with the learning experience.

METHODOLOGY

Learning Context and Experimental Procedures

A multiple-choice question-construction instructional strategy was incorporated into a "Laboratory for Physics" course for a whole semester in the spring semester of 2003. 42 university freshmen from the department of civil engineering in one national university in Taiwan participated in the study.

During the course of this study, each of the enrolled students was required to construct three multiple-choice questions while conducting a variety of physics experiments with the other three randomly assigned group members. In total, ten laboratories related to thermodynamics, electricity, magnetism, dynamics, optics, wave transmission, centripetal force, and atomic physics were set up.

As a routine, students were required to construct and hand in three multiple-choice questions before the end of each lab session while the regular lab report would be due at the beginning of next lab session. To equip students with the basic knowledge and skills of multiple-choice question construction a training session was arranged at the first class session. The following two areas were stressed and explained during the training session—(a) Most frequently encountered types of questions in physical experimentation (observational, procedural or explanatory questions) with model examples; (b) General guidelines on multiple-choice question construction (i.e., DOs and DON'Ts).

At the last class session, a post-session self-report questionnaire was disseminated to participants to be completed individually to collect data on their perceptions and dispositions toward this instructional approach.

Measurement Instruments

The questionnaire mainly consisted of three Likert-scales to collect quantitative data on students' perceptions towards the potentials of question-construction instructional strategy for the support of their learning as well as their satisfaction and anxiety level associated with the activity. The adopted scales were originally developed by Hung [10], who mainly drawn upon Krashen's second language acquisition theory that focused on the affective components that have a decisive impact on successful learning [11]. The scales were adapted to make the items better fit current experimental tasks (Physics experimentation) and the target population involved (undergraduates).

Each statement on the scales was rated on a five-part discrete scale with corresponding verbal descriptions ranging from "strongly disagree" through "disagree," "no-opinion," "agree," to "strongly agree." The Cronbach's alpha values calculated after the study were 0.80, 0.82, and 0.80 for "Students' Perceptions toward the Potential of Multiple-Choice Question-Construction Learning Strategy for the Support of Their Learning Scale," "Satisfaction towards Past Learning Experience Scale," and "Anxiety toward Participating in Multiple-Choice Question Construction Activity Scale," respectively.

In addition, one open-ended question (What do you think of question-construction in class? Specifically, in what aspects does question-construction affect your learning?) was included and intentionally inserted at the beginning of the questionnaire to gather more descriptive and multiple perspectives from participants. Students were advised to provide at least 100 words for the open-ended question before moving on to other parts of the questionnaire.

Data Analysis

Quantitative data from each of the scales were analyzed with one-group *t*-tests, using 3 as the expected mean, first on the summed up data, and then separately on each of the statement. A .05 level of significance was adopted. Qualitative data from the open-ended question were analyzed using a constant comparison method to help understand many of the thought processes provoked during multiple-choice question construction that stimulate changes in students' learning process and outcomes.

RESULTS

Students' Perceptions towards the Potentials of Multiple-Choice Question-Construction for the Support of Their Learning

A 10-item scale and one open-ended question were used to probe into students' perceptions toward the potential values of multiple-choice question construction for their learning. Analysis with one-group *t*-tests, using 3 as the expected mean, on summed up data gathered from the scale found that students'

perceptions toward the potential of multiple-choice question construction for their learning was statistically significant at the 0.0005 level (t =6.44). Separate *t*-tests done on each of the statements, using 3 as the expected mean, found that all statements were statistically significant at the at least 0.005 level (see Table 1). The quantitative data derived from the scale indicated that students regarded multiple-choice question construction as a promising approach for enhancing their performance and competency of physics experiment.

TABLE 1
FREQUENCIES AND T-VALUE OF STUDENTS' PERCEPTIONS TOWARD THE POTENTIALS OF MULTIPLE-CHOICE QUESTION-CONSTRUCTION FOR THEIR LEARNING

I think that…	1	2	3	4	5	t-value
Constructing questions in class helped enhance my ability in the topics covered in physics experiment.	0	2	16	18	6	5.50***
Question-construction activity helped me focus more on the task-at-hand and my learning while conducting physics experiments.	0	0	4	32	6	13.81***
Constructing questions in class didn't really help my learning of the course content.[+]	4	18	16	2	2	-3.37**
Constructing questions in class benefits the learning of physics experimentation.	0	0	14	23	5	7.89***
If continuing constructing questions in class, I am confident that my competency in physics experimentation will increase.	0	2	16	20	4	5.49***
Constructing questions in class helped me understand more of the contents covered in physics experimentation course.	0	2	8	28	4	7.82***
Constructing questions in class made me feel that learning physics experimentation was harder.[+]	1	19	20	2	0	-4.63***
Constructing questions in the class appealed to me as an effective strategy and opportunity for reviewing course-related materials.	0	1	14	24	3	6.95***
Constructing questions in class helped build my confidence toward learning physics experimentation.	0	2	19	17	4	4.80***
Constructing questions in class made me think more deeply and thoroughly.	0	1	5	27	9	10.27***

[+] Negative statement
** <0.005
*** <0.0005

Based on constant comparison data analysis done on students' responses to the open-ended question, the most salient features pertaining to the influences of multiple-choice question-construction on learning were: studying behavior, attitudes and learning outcomes.

Studying behavior

Regarding studying behavior, the most frequently pointed out feature was that it helped students to concentrate more on task-at-hand. The second more prevailing dimension was that it made students preview course materials before heading to the lab. Getting into the habit of reflecting back on one's own thinking and learning was another area that stand out from students' descriptive responses. One final category related to studying habits was that multiple-choice question-construction helped increase inner-group discussion.

A more enthusiastic and positive attitude toward learning

The kind of inertia and passive learning attitudes toward physics experiment residing in students slightly moved toward a more active and enthusiastic one through multiple-choice question construction learning activity, as most students revealed in their responses.

Learning outcomes in terms of learning of physics, overall thinking capability, efficiency

Constructive studying habits and positive attitudes combined in effect helped the learning of physics experiments, as the majority of respondents perceived. The reasons that may account for multiple-choice question-construction's cognitive potentials as provided by participants included that question-posing learning task induced the learners to "*be sensitive to and focus on the important aspects of the experiments*;" "*zoom in on easily forgotten or frequently made mistakes*;" "*discuss more with their group members*;" "*constantly refer to and reflect back on course content*," etc. By such mediating processes multiple-choice question-construction increased awareness and enhanced comprehension, retention, and association, which in the end helped students' learning of physics

experiments.

The second spin-off out of student question-construction activity was students' overall thinking capability. In addition, "*enhancing the efficiency of conducting physics experiment*" was another potential effects associated with question-posing learning experience in physics lab.

Satisfaction towards Past Learning Experience

Generally, students rated favourably to statements on "Satisfaction towards Past Learning Experience Scale." Analysis with one-group *t*-tests, using 3 as the expected mean, on summed up data gathered from the scale found that students' satisfaction toward past learning experience was statistically significant at the 0.0005 level with t = 4.80. Follow-up separate *t*-tests done on each of the statements, using 3 as the expected mean, however, found that 2 items were not statistically significant (see Table 2). In other words, although students as a whole were consonant with statements on satisfaction scale like "*It's enjoyable to be able to construct questions in class*," *"I like to learn through in-class question-construction learning task to facilitate my learning*," they responded conservatively to two statements on the scale—"*I hope that all courses can integrate this kind of instructional approach to let students have a chance to construct questions in class*," and "*I am satisfied with my performance in question-construction learning activity*." Particularly, less than 1/3 of the respondents agreed or strongly agreed to these two statements.

Two reasons were proposed to account for the not-so-favourable ratings on these two statements. With regards to the first statement, different class structures and formats might let students to hold back on rendering their full support for comprehensive implementation of multiple-choice question construction in other classes. Explicitly, physics experiments largely consisted of student-directed hands-on learning activities in which students have more control over the structure and flow of their own learning whereas many classes in higher education were structured toward a instructor-led large class lecture format. On the other hand, in respect of "*I am satisfied with my performance in question-construction learning activity*," more than 60% respondents (61.90%) marked "no opinion" to this statement. This might be due to the fact that in the present study only feedback on overall class performance on multiple-choice question construction task was provided once in a while. Without knowledge of their individual performance on the task, students could not give their answer concerning to their satisfaction with their performance.

TABLE 2
FREQUENCIES AND T-VALUE OF STUDENTS' SATISFACTION TOWARD PAST LEARNING EXPERIENCE

Items	1	2	3	4	5	t-value
It's enjoyable to be able to construct questions in class.	0	2	7	26	7	8.07***
I like constructing questions in class	2	5	16	16	3	2.11**
Constructing questions in class gave me a sense of satisfaction.	1	6	19	12	4	2.02**
I do not like to construct questions in class.[+]	4	13	16	9	0	-2.02**
I like to learn through in-class question-construction learning task to facilitate my learning.	0	2	14	22	4	5.99***
I hope that all courses can integrate this kind of instructional approach to let students have a chance to construct questions in class.	0	11	18	10	3	0.87
I am satisfied with my performance in question-construction learning activity.	0	5	26	9	1	1.15
Constructing questions gave me a sense of under-achievement.[+]	1	23	15	3	0	-5.06***

[+] Negative statement
* <0.05
** <0.005
*** <0.0005

Anxiety toward Participating in Multiple-Choice Question Construction Activity

Analysis with one-group *t*-tests, using 3 as the expected mean, on summed up data gathered from the scales found that students' anxiety was not statistically significant, t = 1.26 (p>.05). That is, overall multiple-choice question-construction task did not significantly heighten students' anxiety toward the learning situation that might arise from the added cognitive tasks associated with the arrangement. Follow-up separate *t*-tests done on each of the statements, using 3 as the expected mean, further found that 3 items were not statistically significant, and 5 were statistically significant (see Table 3). Of the 5 statistically significant results, 3 were in fact significantly favorable of the measured construct. Combining the 3 significantly positive attitudes with the 3 non-significant, nevertheless, favorable

disposition ("*I felt pressure finding out that I need to construct questions in class*;" "*I was nervous about constructing questions in class*;" "*I felt a great sense of relief knowing that I don't need to construct questions in class anymore*."), altogether it indicated that students did not feel anxiety, when faced with multiple-choice question construction task.

In general, students did not associate multiple-choice question construction experience with negative emotional feelings (e.g., worry, frightened, pressure, nervous, etc.). Signs of opposition, hostility or resistance to changes that might arise in responsive to the added responsibility and work as suggested by Silver [5] were not evident in this study. However, students conveyed their worry about "*not being able to come up with good questions*" and "*not perform well on question-construction task*." A closer look at those two significant results in the un-anticipated direction (more anxiety level) yielded that they were more performance-related. To promote smooth adoption and diffusion in their classrooms, teachers may need to deal with these aspects to further alleviate students' elevated anxiety.

TABLE 3
FREQUENCIES AND T-VALUE OF STUDENTS' ANXIETY TOWARD PARTICIPATING IN MULTIPLE-CHOICE QUESTION CONSTRUCTION ACTIVITY

Items	1	2	3	4	5	t-value
Constructing questions in class frightened me.+	3	20	13	6	0	-3.70***
I was not worried that I need to construct questions in class.	2	1	11	24	4	4.74***
I felt pressure finding out that I need to construct questions in class.+	2	12	13	15	0	-0.17
My heart sank knowing that I need to continue constructing questions in class.+	6	20	14	2	0	-5.98***
I was worried about not being able to come up with good questions.+	1	3	7	24	7	5.67***
I was nervous about constructing questions in class.+	1	18	11	12	0	-1.39
I felt a great sense of relief knowing that I don't need to construct questions in class anymore.+	1	7	27	6	1	-0.22
I was worried that I might not perform well on question-construction task.+	0	8	11	20	3	3.13**

+ Negative statement
** <0.005
*** <0.0005

CONCLUSIONS

A student-generated questioning instructional strategy was incorporated in a physics lab session in an attempt to induce learners to spontaneously engage in the activation and use of elaborated learning. Analysis on quantitative data gathered from the questionnaire from the study found that students' satisfaction toward past learning experience, and perceptions toward the potentials of multiple-choice question-construction for the support of their learning were statistically significant. Moreover, learning anxiety was not statistically significant. The obtained results supported the efficacy of multiple-choice question-construction for students' learning without elevating anxiety that might arise from the added cognitive tasks associated with multiple-choice question construction activity. Inductive data analysis of students' responses further indicated that the influences of multiple-choice question-construction were evident in several significant ways, which worked together not only enhanced students' comprehension and retention of the obtained knowledge, but also helped distill a sense of empowerment and learning community within the participants. In summary, multiple-choice question-construction approach helped make students monitor consciously and actively their own learning and induce them to plan, deploy, evaluate and modify strategies during the course of experiment. It is when students perceive themselves as active data-processor rather than data-collectors and compilers, they will become more personally invested in the learning activity and start breaking from their old passive, receiving mode of learning habits [12].

Based on the results yielded from past and the present study, it is suggested that multiple-choice question-construction is an instructional strategy with great potentials that physics instructors might want to consider for incorporating in their classrooms to help students become more active and intellectually engaged learners without relying on a high dosage of technology, which frequently requires major modifications of a traditional structure and additional financial inputs [13].

REFERENCES

[1] Chin C. & Kayalvizhi G., "Posing problems for open investigations: What questions do pupils ask?" *Research in Science and Technological Education*, Vol. 20, No. 2, 2002, pp. 269-87.

[2] English, L. D., "Children's problem posing within formal and in formal context", *Journal for Research in Mathematics Education*, Vol. 29, No. 1, 1998, pp. 83-106.

[3] Koch, A. & Echstein, S. G., "Improvement of reading comprehension of physics texts by students' question formulation", *International Journal of Science Education*, Vol. 13, 1991, pp. 473-485.
[4] Leung, S. S. & Wu, R. X., Problem posing with middle grades mathematics: Two real classroom examples. *Mathematics teaching in the middle school*. Reston, VA: National Council of Teachers of Mathematics, USA, 1999.
[5] Silver, E. A., "On mathematical problem posing", *For the Learning of Mathematics*, Vol. 14, No. 1, 1994, pp.19-28.
[6] Wong, B. Y. L., "Self-questioning instructional research: a review", *Review of Educational Research*, Vol. 55, 1985, pp. 227-268.
[7] Dori Y. J. & Herscovitz O., "Question-posing capability as an alternative evaluation method: analysis of an environmental case study", *Journal of Research in Science Teaching*, Vol. 36, No. 4, 1999, pp. 411-30.
[8] King, A., "Facilitating elaborative learning through guided student-generated questioning", *Educational Psychologist*, Vol. 27, No. 1, 1992, pp. 111-126.
[9] Rosenshine, B. Meister, C. & Chapman, S., "Teaching students to generate questions: A review of the intervention studies", *Review of Educational Research*, Vol. 66, 1996, pp. 181-221.
[10] Hung, M., *The effects of captioned, subtitled and non-captioned television videotapes on foreign language learning*, Unpublished master thesis, National Cheng-Kung University, Tainan, Taiwan, 2001.
[11] Krashen, S. D., *Principles and practice in second language acquisition*. England: Prentice Hall Ltd., 1987.
[12] King, A., "Inquiring minds really do want to know: Using questioning to teach critical thinking", *Teaching of Psychology*, Vol. 22, 1995, pp. 13-17.
[13] Cox, A. J. & Jenkin, W. F., "Enhancing student learning in the introductory physics laboratory", *Physics Education*, Vol. 37, No. 1, 2002, pp. 37-44.