

# Effects of Computer-Aided Personalized System of Instruction in Developing Knowledge and Critical Thinking in Blended Learning Courses

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## Abstract

Two experiments were conducted to assess an online version of Keller's personalized system of instruction, called computer-aided personalized system of instruction (CAPSI), as part of a blended learning design with regard to course knowledge and critical thinking development. In Experiment 1, two lecture sections of an Introduction to University course received a CAPSI assignment while two received an extra paper assignment. In Experiment 2, one lecture section of an Introduction to University course received a CAPSI assignment while another lecture section was assigned a research paper. In the two experiments the CAPSI sections consistently outperformed the sections with which they were compared, indicating that CAPSI is a viable option in higher education.

## Keywords

personalized system of instruction (PSI); computer-aided personalized system of instruction (CAPSI); blended learning; online learning; critical thinking; higher-order thinking; Bloom's taxonomy

Behavior analysis arguably has played a major role in the movement away from the traditional approach to higher education (B. F. Skinner, 1958, 1968; see Pascarella & Terenzi, 1991, 2005). One widely recognized behavioral approach to higher education is Keller's (1968) personalized system of instruction (PSI). The major components of PSI are: (a) instructor-selected textbooks and other textual material; (b) study questions based on the assigned material, (c) student self-pacing; (b) clear study objectives; (c) stress on the written word; (d) textual material divided into small study units; (e) demonstration of mastery of one study unit of material before proceeding to the next study unit; (f) use of more advanced students (typically in another course) to administer unit tests and provide immediate feedback; and (g) use of lectures for motivational purposes as opposed to providing new information. In a PSI approach, the instructor taking on the role of facilitator allows students to become more interactive with the material.

PSI has been shown to be more effective than the traditional lecture method in developing student learning (Kulik, Kulik, & Bangert-Downs, 1990; Kulik, Kulik, & Cohen, 1979). Students in PSI-taught courses have achieved higher exam scores with less instructional time, and professed greater enjoyment toward learning the course material. Differences were more pronounced when performance was measured on essay exams as opposed to multiple-choice exams.

Computer-aided personalized system of instruction (CAPSI) is a computerized form of PSI that has evolved from a mainframe

to a Web-based environment (Kinsner & Pear, 1988, 1990; Pear, 2002; Pear & Crone-Todd, 1999, 2002; Pear & Kinsner, 1988; Pear & Martin, 2004; Pear & Novak, 1996; Pear, Schnerch, Silva, Svenningsen, & Lambert, in press; Springer & Pear, 2008). In addition to being delivered by computer, CAPSI differs from traditional PSI in that rather than having more advanced students outside of the course assess and provide feedback on unit tests, CAPSI enables more advanced students (called peer reviewers) within a course to perform this function. Thus, once a student demonstrates mastery on a given unit, that student may serve as a peer reviewer for that unit. Unit tests must be assigned a pass either by two peer reviewers, by the instructor, or by a teaching assistant in order for the student to proceed to the next unit. If a student does not pass a unit test, the student may try again on a new test of the unit after a period of restudy or appeal the result. The appeal is submitted through the program to the instructor, who then judges the strength of the student's argument and decides whether or not to accept the appeal. CAPSI allows students to select the time (24-hour availability) at which they are ready to write a unit test, based on their personal judgment that they have mastered the material in the unit. The result of a unit test indicates whether the student is correct in this judgment or whether restudying the unit is necessary. Since unit tests are essay and short-answer rather than multiple choice, and students must demonstrate mastery on each study unit before proceeding to the next unit, they cannot progress in a course without understanding the previous required material. This helps ensure that the instructional goals are always appropriate to a student's level of understanding of the course material.

This paper is based on a dissertation submitted by the first author in partial fulfillment of the requirements for the Ph.D. degree at the University of Manitoba.

The combination of classroom instruction with Web-based learning is known as blended learning (Alonso, Lopez, Manrique, & Vines, 2005; Carr-Chellman & Duchastel, 2001; Conannon, Flynn, & Campbell, 2005; Dziuban, Hartman, & Moskal, 2007; Merisotis, 2001). Although CAPSI can be used as a stand-alone method, it is also compatible with a blended approach. Students can take the CAPSI unit tests on their own schedules, collaboration can occur between students and between students and the instructor both in class and on the Internet, assessment can occur from both in-class quizzes and exams and the CAPSI unit tests, while performance-support materials can be provided within the CAPSI program or from other materials, such as textbooks.

CAPSI was designed to foster students' critical or higher-order thinking (e.g., Crone-Todd & Pear, 2001; Crone-Todd, Pear, & Read, 2000; Pear, Crone-Todd, Wirth, & Simister, 2001). There are many definitions of critical thinking, although not all sound behavioral. Skinner perhaps came close to providing a definition in his discussion of thinking as verbal behavior that occurs in a speaker who is also his or her own listener (Skinner, 1957, pp. 438-452). This aspect of critical thinking is captured in the following definition arrived at by a panel of educational experts:

*We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (Facione, 1990, p. 3).*

It has been argued, however, that although PSI, and by implication CAPSI, may be effective for basic knowledge learning, it cannot develop critical thinking skills (Adams, 2004; Budd, 2002). In response, Grant and Spencer (2003) pointed out that any criticism of PSI in regard to teaching critical thinking is equally applicable to university courses in general. More specifically, Reboy and Semb (1991) made the following four points: First, PSI is a delivery system that is not dependent on content; therefore, content within the PSI delivery system can be focused on developing critical thinking skills by using a systematic questioning technique (Quitadamo & Brown, 2001). Second, PSI has been successfully used in courses requiring critical thinking skills. Third, research has shown that "students enrolled in PSI courses have improved their higher-order cognitive [thinking] skills" (p. 212). Fourth, PSI allows for "early diagnosis of inadequate reasoning because of frequent student contact and assessment" (p. 213).

The emphasis in CAPSI on written answers, providing written feedback when assessing other students' answers, and writing appeals develops critical thinking as discussed above (i.e., engaging in verbal behavior under the control of the verbal behavior of oneself as well as that of others). Teaching by computer-mediated communications encourages interacting through written forms of communication, which it has been argued may result in increased reflection and greater problem-solving performance (Garrison & Kanuka, 2004; King, 1995). The range and quality of interactive dialogue that can be facilitated through CAPSI is consistent with this view.

The present study sought to examine in two experiments conducted in two courses the pedagogical effectiveness of CAPSI as a component of a blended course with respect to students learning course material and developing critical thinking skills.

## ■ EXPERIMENT 1

Introduction to University at the University of Manitoba is a first year university course that introduces students to the skills they will need for other university courses, thus helping students make the transition from high school to university. The course normally requires students to write three essay assignments. The hypothesis in Experiment 1 was that completing a CAPSI assignment develops course knowledge and critical thinking skills above that of writing a third essay assignment.

This hypothesis was tested using the final examination and a critical thinking assessment tool called the Applied Critical Thinking Measure (ACTM). The final exam consisted of three types of questions exemplifying three levels of Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956): (a) knowledge of the course textual material; (b) ability to apply either problem solving skills or to illustrate their knowledge of Bloom's taxonomy; and (c) use of Hegel's Dialectic as evidence of critical thinking.

## ■ METHOD

### PARTICIPANTS

The participants were 364 University of Manitoba students enrolled in Introduction to University for the Fall 2006 13-week academic term. The course was only open to students who had completed less than twelve credit hours.

### PROCEDURE

The course had four lecture sections: two CAPSI sections and two non-CAPSI sections. Eight lab sections accompanied each lecture section. The sections were comparable because students signed up for particular lecture sections and corresponding lab sections without prior knowledge of the methods to be used in the different lecture sections.

Course requirements were similar across all four sections. The only difference was that students in the two CAPSI sections were required to complete two APA-formatted essays (roughly 1000 words each) and a CAPSI assignment, while students in the two the non-CAPSI sections were required to write three APA-formatted essays (roughly 1000 words each) as a part of course requirements

Four different instructors were responsible for each of the four lecture sections of the course. Each instructor delivered the in-class lecture component and supervised eight teaching assistants (TAs) for the eight labs associated with each lecture section. For the two CAPSI sections, one instructor was the first author; the other instructor had previous knowledge of the CAPSI program. All instructors had a minimum of three years experience teaching the course, with the instructors of the non-CAPSI sections having greater experience teaching the course.

Attending regularly scheduled instructor meetings was a requirement for teaching the course. One component of these meetings was to insure that all instructors were aware of the

general objectives and the teaching and learning expectations of the course. This approach increased the teaching consistency across the various sections to insure that all students received the same level of instruction.

TAs were assigned on the basis of their availability to their respective lab sections. During the labs the TAs led group exercises, facilitated individual presentations, and assisted in the development of writing skills. The TAs also graded essay assignments, the final exam, and, in the CAPSI sections, unit tests that were not assessed by peer reviewers. Unit tests were graded on a mastery basis. For mastery to be achieved, the peer reviewers or TAs determined that three questions related to the unit were answered with 100% accuracy.

Lectures were 75 minutes long and occurred once a week on either Tuesdays or Thursdays, depending on the lecture section. Labs were 75 minutes long and occurred once a week on the Tuesday or Thursday that was not being used for its associated lecture.

All lecture sections used the same textbook: *Study and Critical Thinking Skills in College* (Sixth Edition) by Kathleen McWhorter (2006). Students were also given a course outline, which detailed the course requirements. Students in the CAPSI sections received information about the CAPSI assignment, while students in the non-CAPSI sections received information about writing a third essay.

All students wrote the same final exam in the same exam period after lectures had ended. The final exam consisted of three components: (a) a knowledge component; (b) an applied component; and (c) a critical thinking component.

### THE CAPSI PROGRAM

In a lecture session during the second week of classes the students in the CAPSI sections were shown and directed to the CAPSI website at [www.capsi.org](http://www.capsi.org). At the same time, a demonstration of CAPSI was conducted to show students how to move through the system to take unit tests and to peer review other students' unit tests.

Prior to the beginning of the course, the instructors for the two CAPSI sections gave the TAs in their sections a demonstration of the CAPSI program, with instructions regarding proper feedback procedures. In addition, both instructors maintained weekly contact with the TAs either by email or in person in order to address any concerns and to provide general feedback and motivation.

The CAPSI program required that unit tests be graded by either a TA or by two peer reviewers. When assigning peer reviewers, the CAPSI program selected two peers with the lowest number of peer-reviewing points who had passed the unit being graded and who had agreed to be available to grade within 24 hours after the unit test to be graded was submitted. When two peer reviewers assessed a unit test, both had to independently agree that the student demonstrated mastery of the material in order for the program to record the test as a pass. All peer reviewing was anonymous with respect to both the test writer and the peer reviewer. There was a built-in appeal process for arguing the validity of a given answer.

The CAPSI assignment was designed for students to pass 20 unit tests and to peer review 10 unit tests. Each CAPSI unit

corresponded to one chapter from the course textbook. Each unit test was worth .75 % of the final grade, while each peer review was worth .5%. For each unit, students were required to answer 3 randomly generated questions from the CAPSI unit corresponding to the appropriate chapter from the textbook. The questions for each unit were composed according to the requirements for the six levels of Bloom's taxonomy and were designed to test the students' understanding of the textbook material.

### THE APPLIED CRITICAL THINKING MEASURE (ACTM)

The ACTM and the associated scoring sheet were designed and researched by Dr. Robert Renaud of the Education Faculty at the University of Manitoba. (Regehr, 2003; Renaud & Mandzuk, 2006). Although the psychometric properties of the ACTM have not been extensively studied, there were two reasons for choosing it as the critical thinking measure. First, both CAPSI study unit questions and the ACTM items implement a question-answer method in which the answers are in a written as opposed to a multiple-choice format. Second, the ACTM is consistent with the view of critical thinking discussed earlier in this paper.

The ACTM was administered to students attending the last lab at the end of the term. There was no requirement that students had to attend the lab or participate in writing the ACTM. Therefore, the number of students writing the ACTM was lower than the number of students actually writing the exam.

In this measure, students were asked to respond to three vague situations they were likely to be familiar with. They were then asked to make a "Yes," "No," or "Not sure" selection based on what they had read and the question that was asked at the end of the scenario. Students were then directed to either write three statements that justified their "Yes" or "No" decision; or, if "Not Sure" was selected, to specify three questions regarding what information they would need in order to make a justified decision.

A grading rubric was supplied to assessors to rate the responses to the ACTM scenarios. Each written response was rated on a scale from 0 to 1 for a "Yes" choice, 0 to 2 for a "No" choice, and 0 to 3 for a "Not Sure" choice. The "Not Sure" responses were given the higher rating because the vague nature of the scenario opened it to greater critical analysis and questions. Therefore, a student could obtain a critical thinking score from 0 to 9 points on each scenario, achieving a total score from 0-27 for the complete assessment. A sample scenario is as follows:

According to a recent report, in Canadian prisons, the sentences are too short and the time spent behind bars is too easy. In fact, a considerable number of those convicted of violent crimes are released before they have served even a third of their expected sentences.

Do you agree that the prison system in Canada is far too soft, especially with more serious offenders?

(circle one) YES NO NOT SURE

In the boxes below, if you answered YES or NO, please give three distinct reasons why (one reason per box). If you answered NOT SURE, what would be the three most important or relevant things (one point per box) you want to know before deciding whether or not the prison system in Canada is too soft?

## DATA COLLECTION AND RELIABILITY MEASUREMENT

The TAs did the initial scoring of the final exam for the students in their respective lab sections using a grading rubric provided by the instructor. To assess the reliability of the final exam grades a random sample of 20 final exams was re-scored by an independent grader using the same rubric that the TAs used. The independent grader was blind with regard to the lecture sections the papers were from. The formula used to assess reliability was the lower score divided by the higher score. If the scores were the same, then the IOR was 1.00 for that assessment. Using this measure a mean reliability score of .85 was obtained.

The ACTMs were scored by the first author and two independent reliability scorers who were blind as to the lecture sections that the ACTMs were associated with. The total number of ACTMs used for the post ACTM statistical analysis was 132; of these, 45 were rescored, resulting in 34.09% of the assessments being rescored. The formula used for the reliability measure was the lower score divided score by the higher score. If the scores were the same, the reliability measure was 1.00 for that assessment. Using this measure a mean reliability score of .82 was obtained.

## DATA ANALYSIS

The data were analyzed using an analysis of variance (ANOVA) instructors-nested-within-teaching-method design. In this design, students were nested within instructors and the instructors were nested within the teaching methods. Four comparisons between the CAPSI and non-CAPSI conditions were made in this experiment and will be presented in the results sections in this order: (a) total scores on the final exam; (b) scores on the critical thinking question of the final exam; (c) scores on the two content questions of the final exam; and (d) scores on the ACTM.

## RESULTS

### FINAL EXAM

The CAPSI sections scored higher than the non-CAPSI sections on the final exam. The overall mean of the CAPSI sections was 69.18 (s.d. = 6.46) and that of the non-CAPSI sections was 65.95 (s.d. = 6.35), resulting in a difference of 3.23 in the final exam score between the CAPSI and non-CAPSI conditions ( $p = .053$ ). The effect size as indexed by a partial eta-squared would be classified as minimal (partial  $\eta^2 = .01$ ; Tabachnick & Fidell, 2007).

### CRITICAL THINKING EXAM QUESTION

The overall mean of the CAPSI sections was higher ( $M = 28.25$ , s.d. = 6.46) than the non-CAPSI sections ( $M = 26.74$ , s.d. = 6.35) resulting in a difference of 1.51 between the conditions. The mean difference between the two conditions for the critical thinking question was significant at the .05 level ( $p = .026$ ). Although this difference was significant at the .05 level, the effect size would be classified as small (Partial  $\eta^2 = .01$ ; Tabachnick & Fidell, 2007).

### QUESTIONS ON COURSE CONTENT

The CAPSI sections scored higher than the non-CAPSI sections on the course content questions ( $M = 42.82$  vs. 40.26). However, this difference was not statistically significant (the s.d.'s were

22.94 and 17.99, respectively).

## ACTM

The CAPSI sections scored higher than the non-CAPSI sections on the ACTM ( $M = 9.33$  vs. 8.62). However, this difference was not statistically significant (the s.d.'s were 5.13 and 6.18, respectively).

## DISCUSSION

The major finding of Experiment 1 was that students in the CAPSI sections scored higher on the final exam than students in the non-CAPSI sections. This appears to be due primarily to the performance on the critical thinking question, because there was a significant difference between the conditions on that question, but not on the content questions. Although there were non-significant differences between the CAPSI and the non-CAPSI sections on the content questions and the ACTM, these differences did favor the CAPSI condition.

The results support earlier findings on the effectiveness of PSI (Kulik et al., 1979, 1990; M. Skinner, 1990). The results also support the findings that students in blended learning courses perform as well or better than students in strictly lecture-based courses (Means, Toyama, Murphy, Bakia, & Jones, 2009; Pereira, Pleguezuelos, Molina-Ros, Molina-Tomas, & Masdeu, 2007).

Although the main differences favored the CAPSI condition, the effect sizes were small. This contrasts with the large effect sizes that have been obtained in comparisons of PSI with the lecture method. Possible reasons for this discrepancy will be addressed in the General Discussion section. With regard to the lack of a significant effect on the ACTM scores, it should be noted the power of the statistical test could have been decreased in three ways. First, there were fewer participants who wrote the ACTM than who wrote the final exam. Second, conducting the ACTM in the labs could have increased the variability of the scores in that the TAs may have provided different instructions to the students, or provided different responses to questions from the students. Third, it is possible that the ACTM was not sensitive enough to pick up some of the subtle effects that CAPSI may have had on developing critical thinking.

## EXPERIMENT 2

The high variability between instructors in Experiment 1 may have tended to mask differences between the CAPSI and non-CAPSI conditions. Therefore, to eliminate variability between instructors, Experiment 2 compared the CAPSI and non-CAPSI treatments in two lecture sections of Introduction to University that were both taught by the same instructor. In addition, whereas Experiment 1 examined both the development of knowledge and critical thinking, Experiment 2 focused exclusively on the latter. To this end, the CAPSI questions were only of the highest level – Bloom's level 6. That is, the CAPSI component used only questions that required students to evaluate a position supported by information from the course textbook. Other differences with Experiment 1 are detailed below. The hypothesis to be tested was that student participation in a CAPSI assignment in which students are asked to supply higher level thinking responses as a component of a blended designed

course develops student critical thinking more effectively than writing a third essay.

## ■ METHOD

### PARTICIPANTS

The participants were 276 University of Manitoba students enrolled in two lecture sections of Introduction to University for the Fall 2007 13-week academic term.

### PROCEDURE

One lecture section was designated the CAPSI section and the other the non-CAPSI section. The two lecture sections were scheduled for either Tuesdays or Thursdays. Through a simple random method of flipping a coin and having a third party call the toss, it was determined that the Thursday lecture section would receive the CAPSI assignment.

The instructor in this experiment was Instructor 1 from Experiment 1. Eight TAs were selected by the department in charge of the course and matched with lab sections based on availability. There were eight lab sections associated with each of the two lecture sections, with each lab section having a maximum enrolment of 20 students. The labs were scheduled once a week on the Tuesday or Thursday that was not being used for the associated lecture.

The number of students originally registered in the CAPSI section was 137 and the number of students originally registered in the non-CAPSI section was 139. As in Experiment 1, students signed up for the lecture sections without prior knowledge of the teaching methods used in the different lecture sections.

The textbook used for the course was *ARTS 1110 Introduction to University: Custom Edition for the University of Manitoba* (2007). The book was a compilation of chapters from McWhorther (2006) and Browne and Keeley (2007). All students used the same textbook and were given the same course outline.

All students were required to write two 1,000-word APA-style essays. However, students in the non-CAPSI section were required to write a third 1,000-word APA-styled essay while students in the CAPSI section had CAPSI as a required assignment. In addition, students in both lecture sections were given an ACTM prior to the beginning of the CAPSI assignment and at the end of the term. Different questions were used in the two administrations of the ACTM. This was done to avoid a practice effect from writing answers to the same questions in the pre-ACTM assessment. The CAPSI program was set up in a similar manner to that of Experiment 1.

### CAPSI ASSIGNMENT

In Experiment 1, the CAPSI program amalgamated all students in the CAPSI sections and all TAs as part of the same large class. In Experiment 2, the CAPSI program treated the eight lab sections as separate classes. That is, each lab section was a separate CAPSI class. TAs only assessed answers from students in their lab section; and students only peer reviewed other students in their lab section. The reasons for this were: (a) to increase the efficiency of certain aspects of the program and (b) to build a greater sense of responsibility and communication within the

sections. Students could ask the TA directly about progress through CAPSI or other specific questions related to the assignment.

Similar procedures were followed regarding TA training. The only changes being first, that instruction was provided just prior to the beginning of the CAPSI assignment, not the beginning of the course. Second, only the one instructor maintained weekly contact with the TAs either by email or in person in order to address any concerns and to provide general feedback and motivation.

Whereas in Experiment 1, students could access the program from the first week of classes, in Experiment 2, students were able to take unit tests only in the last third of the academic term. The purpose of this was to correspond to the timing of the required third essay assignment of the non-CAPSI section and to the material that was presented in the lectures. As in Experiment 1, in the week prior to the beginning of the CAPSI assignment, students in the CAPSI section were shown and directed to the CAPSI website and given a demonstration of the program.

The design of the questions for the CAPSI assignment followed J. M. Keller's (1999) model of attention, relevance, confidence, and satisfaction (ARCS). In following this model, small modules were set up to help students master one unit at a time, provide students with clear criteria, and deliver effective and timely feedback for motivation and confidence.

Only the final eight chapters of the textbook were used. These were the chapters that focused on the aspect of critical thinking and critical assessment. These eight chapters were then condensed into five units.

The CAPSI assignment was designed for students to pass 5 unit tests and to peer review 5 times. Each unit test consisted of 1 question randomly selected by the CAPSI program from a database of questions. Each question was worth 2% of the final grade and each instance of peer reviewing was worth 1%. Therefore, if a student completed all 5 unit tests and peer reviews, the student would have earned 15% of his or her grade. A student received a final grade on the assignment associated with the number of units passed and peer reviews completed.

The questions for each unit were designed to correspond to the appropriate chapters from the course textbook. The answers could not be found in the chapters per se; however, information from the chapters could be incorporated into the answers. The instructor originally selected the questions, which were then submitted to the first author for approval prior to inclusion in the CAPSI program. The questions were either taken from letters sent into a daily newspaper or were designed by the instructor for the course. All references to the source of the questions, as well as authors of the letters were removed from the original letter.

### DATA COLLECTION AND ASSESSMENT

Students in both lecture sections were given a pre-ACTM prior to the beginning of the CAPSI assignment in the CAPSI section or third essay assignment in the non-CAPSI section. The ACTM was administered to both lecture sections in the last week of classes. The pre-ACTM contained problems similar to, but different from those the students received on the ACTM at the end of the term. The same grading rubric as in Experiment 1 was

used to assess the responses to the ACTM scenarios. Three critical thinking questions were assigned in the Pre-ACTM, while a different set of three questions assigned in the Post-ACTM. The questions used on the Pre-ACTM and ACTM were the same ones that were used in Experiment 1.

### INTER-RATER RELIABILITIES

Reliability of assessing the Pre-ACTM and the ACTM were calculated in the same manner as in Experiment 1. The reliability measures obtained were .74 and .83, respectively.

## RESULTS

The mean pre-ACTM score for the CAPSI section was only slightly higher than the non-CAPSI section (3.83 vs. 3.81, *s.d.*'s = 1.94 and 1.80, respectively), indicating that the two lecture sections were approximately equal in critical thinking prior to the CAPSI assignment. However, the difference between the CAPSI and non-CAPSI sections increased on the ACTM by a factor of over 41 (.0174 vs. .7295; *s.d.*'s = 1.79 and 1.96, respectively).

The scores on the pre-ACTM did not differ significantly between the two lecture sections. However, the scores on the ACTM differed significantly ( $p = .03$ ) using a two-tailed test. The effect size as indexed by Cohen's  $d$  was .389, which would be classified as medium (Cohen, 1988, p. 25).

## DISCUSSION

The results indicate that the CAPSI program was effective in increasing critical thinking skills as measured by the ACTM. The results on the pre-ACTM indicate that the students in both lecture sections were at approximately the same level of critical thinking ability at the start of the CAPSI assignment or third essay assignment. While students in both lecture sections did show an increase in critical thinking ability, the CAPSI section showed greater improvement than the non-CAPSI section.

This result supports Grant and Spencer's (2003) point that PSI is applicable to teaching critical thinking in post-secondary courses. The result is also consistent with Reboy and Semb's (1991) finding of improved higher-order thinking skills in students enrolled in PSI courses.

## GENERAL DISCUSSION

The positive outcomes in both experiments indicate that CAPSI is an effective component for developing critical thinking and course knowledge in blended designs. Two general reasons why the effects observed may not have been stronger are as follows. First, as Terenzini, Springer, Pascarella, and Nora (1995) pointed out, "one possible explanation for the absence of significant effects [in comparing differences between instructional methods in university courses] may be that a semester course experience may be too brief to produce any measurable impact" (p. 24). In other words, the differences observed in this experiment might have been more pronounced in a longer course in which CAPSI was used for a longer period of time. Second, not all students in the CAPSI conditions completed the unit tests. Therefore, the consistently positive results of the CAPSI conditions were based on a smaller amount of exposure to the CAPSI component than

would be indicated by a superficial look at the procedure.

We now discuss some specific effects that with regard to developing critical thinking and learning course content.

### DEVELOPING CRITICAL THINKING

Contrary to the criticism that behaviorist methods are not effective for developing higher level thinking skills (Budd, 2002), scores on critical thinking measures showed a consistently positive difference in favor of the CAPSI sections in the two experiments. The results from these experiments add to the findings of Reboy and Semb (1991) that PSI can be used to teach critical thinking at levels of achievement that exceed those attained in a lecture-discussion format. As stated by Reboy and Semb (1991), the positive effect of PSI on critical thinking could be due to early diagnosis of inadequate answers that increases the probability of detecting and correcting errors in reasoning. The early diagnosis and correction in CAPSI is attained by receiving feedback on written answers and on appeals that argue the merits of specific answers.

Other factors that could have contributed to this result are the types of questions asked, especially in Experiment 2, and the inclusion of peer reviewing. As stated earlier, Reboy and Semb (1991) pointed out that the components of the PSI delivery system can be focused on developing higher-order thinking skills. That peer reviewing might be a factor contributing to the development of critical thinking is consistent with Terenzini et al. (1995), who stated that interactions among students seems to have a positive influence on critical thinking. For CAPSI, the interactions involving peer reviewing could have produced a similar enhancement of critical thinking. Peer reviewing can be viewed as a highly systematic written dialogue between students on specific course information (Carr-Chellman & Duchastel, 2001).

### LEARNING COURSE CONTENT

The consistent superiority of CAPSI is in accordance with the findings of greater college-level exam scores for PSI type learning (Kulik et al., 1979, 1990; M. Skinner, 1990). It is also consistent with the findings of Dzubian et al. (2004), and Pereira et al. (2007) who showed that students in blended learning courses achieved higher scores than students in lecture-based courses. The small effect sizes found in the present study are not consistent with the larger effect sizes found in previous studies on PSI. However, most of the prior studies compared PSI with a straight lecture method. In the present study, steps were taken to ensure that the methods used in the comparison sections were as effective as possible; e.g., assigning essays, and providing TAs that assisted students in their learning. In addition, in both experiments, CAPSI was blended with lectures that were identical across sections. That the CAPSI sections still consistently outperformed the sections with which they were compared with in regard to course content learning and critical thinking supports the view that CAPSI is a highly effective empirically based educational methodology.

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