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## A social constructivist approach to computer-mediated instruction

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### Abstract

A computer-mediated teaching system, called computer-aided personalized system of instruction (CAPSI), has been developed that incorporates a social constructivist approach. This educational philosophy maintains that human learning occurs primarily through a socially interactive process. In CAPSI, course material is divided into study units, and the instructor prepares study questions on each unit. The study questions require verbally composed answers. In addition, the study questions in CAPSI often do not specify any one correct answer; instead the quality of the answer depends on how well it is argued as judged by the feedback it evokes from others. All students receive feedback on their performance from more advanced students. In addition, the more advanced students learn from the answers of the less advanced students. Data presented in this report show that, consistent with social constructivism, students in a CAPSI-taught course receive and give a large amount of substantive feedback. © 2002 Elsevier Science Ltd. All rights reserved.

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In an epilogue to his classic work *Verbal Behavior* (1957), Skinner stated:

In many ways, then, this seems to me to be a better way of talking about verbal behavior, and that is why I have tried to get the reader to talk about it in this way too. But have I told him [or her] the truth? Who can say? A science of verbal behavior probably makes no provision for truth or certainty (but we cannot even be certain of the truth of that) [p. 456].

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The above quotation is consistent with a philosophy that is known as social constructivism (e.g. Hacking, 1999, p. 33). In conjunction with the theme of Verbal Behavior, the quotation makes it clear that Skinner recognized that his theory is (1) a construction that was shaped by his social environment, and (2) not a reflection or representation of some underlying reality. This is consistent with Skinner's view of how scientific verbal behavior (i.e. scientific knowledge) is constructed, which is a special case of the construction (or composition) of verbal behavior in general. According to this view (and social constructivism), a speaker composes (or constructs) new verbal behavior on the basis of linguistic practices that have been reinforced by his or her verbal community. Or, stated another way, a speaker constructs the new verbal behavior on the basis of the speaker's transactions with his or her environment.

The philosophy of social constructivism has given rise to social constructivist pedagogical theory (Driscoll, 1999; Gagné, 1987; Jonassen, 1994; Perkins, 1992). In practical application of the theory, social constructivism stresses the importance of feedback (reinforcement) for constructed verbal behavior within a milieu in helping an individual construct his or her knowledge. There are two analogies that are particularly apt in illustrating this approach to education. A familiar example of social constructivism in everyday life, which we draw on here as a useful analogy, is the way in which a person learns his or her native language. The person learning his or her native language receives feedback from speakers in his or her culture. In the beginning, this feedback comes from more advanced speakers. But less advanced speakers also shape the verbal behavior of more advanced speakers. In a social constructivist system, learners are teachers and teachers are learners, just as in a verbal community speakers are listeners and listeners are speakers. The individual learns his or her native language by interacting verbally with others. Having learned to verbally interact with others, the individual can then verbally interact with himself or herself. That is, the individual learns to engage in an internal dialogue. The form that this internal dialogue takes may be called the individual's construction of meaning. Thus, according to social constructivism, the individual learns early on, even as language development begins, to construct his or her knowledge and meanings through interaction with others.

We turn now to the other analogy with social constructivist pedagogy: science. As already indicated, according to Skinner (1957) the construction of scientific knowledge (i.e. scientific verbal behavior) is a special case of composition. For example, after making what they believe to be a discovery, scientists communicate their findings to peers who provide feedback (i.e. reinforcement or punishment). Even scientists who work strictly in isolation must eventually make their findings known to others in order for those findings to form part of a body of scientific knowledge. Science may be regarded as a continuous dialogue, which involves scientists receiving feedback from, and providing feedback to, other scientists about hypotheses, theories, and purported discoveries. Scientific findings must be communicated in the appropriate scientific language to be accepted, and the individual scientist receives both positive and negative feedback for his or her scientific offerings. Generally the feedback shapes the scientist's behavior in one of two ways: he or she may conform to it, or may redouble his or her efforts to refute it. In either case, the feedback has a profound effect on the scientist's internal dialogue and how the scientist constructs his or her knowledge. Occasionally a given construction may be radically different from the prevailing view and at the same time more effective in dealing with the data. That is, it may seem to the scientist to be "a better way of talking about" a particular area of study. In such cases a "paradigm shift" (Kuhn, 1962) may occur in which a formerly minority view replaces the majority view.

If we regard these analogies as two ends of a continuum, academic learning lies somewhere between them (Fig. 1). Social constructivist teaching should help students construct their own solutions to problems rather than simply accept the solutions of others. This, however, is not easy to accomplish. There is no evidence, for example, that it will occur naturally in all individuals simply because they are presented with the opportunity to solve problems in a social setting. In combination with computer-mediated technology, behavioral technology can help to overcome some of the problems involved in implementing a social constructivist education. Computers can keep continuous track of each student in a course and make instant decisions based on that student's current performance. Many classroom instructors who go online, however, try to transfer standard classroom methods to the computer environment. The results are often unimpressive. Some online courses consist of the instructors' lecture notes and some type of web-based discussion group. Some students participate in the discussions but many do not. Many more will participate if participation is made part of the course requirement, but the amount of writing students generate in an online discussion course can overwhelm an instructor.

At the University of Manitoba we teach some of our courses using an online method that is grounded in both behavioral and social constructivist pedagogical practices. Because the method is based on Keller's (1968) personalized system of instruction, we call it computer-aided personalized system of instruction (CAPSI, see Pear & Crone-Todd, 1999). Keller's approach is based on the research findings and teachings of Skinner (1968), who was a close friend. As discussed later, the process of learning in the CAPSI environment involves a high level of student–student and student–instructor interactions; hence, there is a social milieu in which students are constructing their knowledge.

The material for a CAPSI-taught course is in text and graphic format—which may be either online or in a standard textbook. There are no lectures because it is assumed that any material that can be delivered in a lecture can be presented in text or graphic format. In addition, students are provided with questions that they can answer on the basis of the course material. The questions are consistent with the view that learning an academic subject area consists, to a large extent, in learning a specialized language. Thus, the questions are not multiple choice; rather, they are designed to generate writing or talking about the subject area. That is, the questions require composed or constructed answers.

The questions (or problems) are constructed in a manner that is consistent with social constructivism. Contrary to what one might expect, however, this does not rule out questions that call for rote learning. Paul Feyerabend, one of the leading figures in the philosophy of social constructivism (Hacking, 1999, pp. 96–99), cogently argued that the rote learning is a necessary precursor to constructing any meaningful learning or knowledge. In his classic *Against method* (1975/1993, pp. 194–195), Feyerabend described the role of rote learning both in the child's early

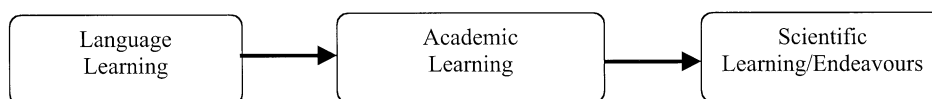


Fig. 1. A representation of language, academic and scientific learning. Academic learning is seen to be somewhere between language learning and scientific learning. Hence, language is necessary prior to academic learning, and both are required for scientific thinking. All occur in a milieu, in which the person constructs his or her language, academic, and scientific knowledge on the basis of their experience with the environment and others.

language acquisition and in the building (or construction) of scientific and logical knowledge (see also Feyerabend, 1987b, p. 270; 1999, pp. 125–126). In other words, learning about the constructed knowledge of others is a necessary element in the construction of one's own knowledge.

Rote learning is useful only if it eventually leads to questions that require the student's active participation in learning and reflection about the material. To ensure that this occurs, we use a modified form of Bloom's taxonomy in the cognitive domain (Bloom, 1956; Crone-Todd, Pear, & Read, 2000) to gauge the type of participation each question requires of the student. The taxonomy sorts questions into categories or levels. Rote learning is at the lowest level (called the "knowledge" level). The next level is comprehension. Basically, a student comprehends a concept if he or she can restate it in his or her own words. The next level is application, at which a student must be able to apply a concept to solve a new problem. The next two levels are analysis and synthesis, which require, respectively, breaking a concept into its parts and assembling concepts or their parts to form a new whole. At the highest cognitive level is evaluation, which requires constructing cogent arguments to defend particular positions with respect to some aspect of the course material. Clearly the highest levels are most consistent with constructivism because they involve the construction of new knowledge on the part of the student. Evaluation, however, incorporates the other levels. In addition, students tend to find the lower level questions easier to master initially, which tends to reduce their frustration with learning new material. Therefore, we try to have all levels represented for each major concept in the course, but we also try to have the ratio of higher-to-lower-level questions gradually increase as the course progresses. This is in accordance with the principle of strongly supporting the student's construction of knowledge early and gradually decreasing the support, as has been emphasized (under one name or another) by all global learning theorists. Vygotsky (1962, 1978) used the term "scaffolding", which essentially refers to the process involved in having students move from assisted learning to non-assisted learning about a given subject. Skinner (1953) used terms such as "shaping" and "fading" to describe the procedures to use to help ensure that scaffolding is successful.

Scaffolding also comes into play in that the course material is divided into a number of manageable units. When a student feels that he or she has mastered the material in a given unit, the student requests a test on that unit from the computer. The computer presents a random sample of the questions on that unit to the student. After the student has answered the questions, he or she submits them for marking and feedback. There are several points we can note immediately about the testing process that make it consistent with a constructivist approach. First, as already mentioned, the questions are not multiple choice: the student must compose the answers to the questions. Second, there is no clear demarcation between testing and teaching. The students learn by studying and reflecting on the material in two ways: (1) by constructing answers to potential questions that will be posed to them on tests, and (2) by providing positive feedback and assistance to other learners (i.e. as a peer-tutor) to help construct their knowledge about the material. Thus, the testing method is the teaching method. Third, there is no such thing as failure; if a student does not demonstrate mastery of the material, he or she takes another test on the unit after a brief restudy period. Fourth, the student may cancel a test without penalty anytime after having requested it and before submitting it. This encourages the student to evaluate his or her own learning (construction of knowledge) of the material. Finally, there is no predetermined answer key which would constitute the only acceptable answers to questions; rather, students are simply asked to completely and correctly answer the questions. Hence, the decisions made about

mastery of the material are made by the feedback providers; in so doing, they help scaffold students' construction of knowledge within a socially situated context.

The assertion that CAPSI fits a social constructivist paradigm implies that students in a CAPSI-taught course give and receive a large amount of substantive feedback to and from each other. The current study provides data regarding this conjecture.

## **1. Method**

### *1.1. Participants*

The participants were 24 students enrolled in “Principles of Behavior Modification,” an undergraduate psychology course at the University of Manitoba.

### *1.2. Instructional materials*

Course manuals, available at the campus bookstore, included the following: (1) study questions and their identified levels according to the modified taxonomy (Crone-Todd et al., 2000); (2) descriptions of the levels, along with examples of each type of question; and (3) instructions about how to provide feedback on tests. The instructions suggested the following points for consideration when providing feedback: (1) use of original examples, (2) whether the answer was clear, (3) whether all relevant key concepts were adequately addressed, and (4) whether the answer was in the student's own words.

### *1.3. Procedure*

The course was divided into 10 study units, with about 20–30 short-essay or short answer study-questions for each unit. The study questions, which were based on material from the textbook, were available to the students at the beginning of the course. The primary functions performed by the CAPSI software were to (1) randomly generate and electronically deliver a unit test to a student, upon his or her request, (2) assign marker(s) to each completed unit test, (3) electronically deliver the completed unit test to the selected marker(s), (4) electronically deliver the test back to the student with written feedback from the marker(s), (5) advance the student one unit in the course if each proctor assigned to mark the test, or the teaching assistant or instructor, indicated that the student had demonstrated mastery of the unit, (6) assign credit to students for marking unit tests, (7) deduct points for late marking, (8) keep track of and update each student's eligibility and availability to mark, (9) process appeals, (10) administer midterm and final examinations, and (11) record all transactions in the course (including the feedback that students' received on their answers to the questions on unit tests). Students who marked unit tests were called proctors, and they received a small amount of credit in the course for performing this function. If there were at least two students who had passed (i.e. demonstrated mastery on) a given unit a test was on when the test was submitted, the two who had proctored the fewest number of times and who had indicated their availability were assigned to mark the test. Either the instructor or the teaching assistant was assigned to mark a test if there were not two students

eligible and available to be proctors for the test. A 24-h time limit on marking unit tests ensured that students received feedback promptly.

It was the proctors' responsibility to make pass/restudy determination on unit tests. Proctors were instructed to assign a pass only when all answers demonstrated mastery of the relevant facts or concepts (i.e. the answers were "completely correct"). In order for a test to be considered a pass, both proctors had to assign a pass to it. The proctors were instructed to give positive, constructive feedback in a nonpunitive manner. However, there was very little monitoring of the feedback that the proctors gave or their decisions. That is, the social-interaction system involved in CAPSI functioned with little input from the instructor or teaching assistants. It is this feature that most conforms to a social constructivist pedagogy.

#### 1.4. Data analysis

After the course was over, the feedback was analyzed according to whether it was minimal or substantive. Feedback was minimal if it consisted of a short statement that provided vague praise or criticism that was not specifically directed to the content of the answer (e.g. "Good!" "Well written", "Needs work"). Feedback was substantive if it included a specific reference to the actual content of the answer. Examples of substantive feedback include prompts or praise for some

Table 1  
Examples of minimal and substantive feedback

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##### *Minimal*

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Very good answer.  
This answer is pretty good although lacking in a few areas.

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##### *Substantive*

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Very good—just be careful of replacing "factors" with "issues", since they do not necessarily mean the same thing.

Yes, your answer is partially right but you have not indicated that the instructions may influence an individual to work for delayed reinforcements. Ex. Getting an A as your mark is delayed for several months from now. Also adding instructions to reinforcement programs may benefit young children to follow instructions. Instructions are not necessary but it does benefit the people who do know the instructions. This is on page 37/38 of your text book.

Good answer, although next time try to answer the questions in order, maybe by putting into your own words or just reorganizing words.

Good definition. Although some of the material could have been put more in your own words.

This is a fairly good answer; however, it could include a specific statement about the distinction between the two processes at the beginning, and then the examples. Also, the extinction burst is not likely to occur in the "middle" of the program—it is more likely to occur at the beginning. Your examples are excellent, and demonstrate that you are understanding and applying these concepts!

You are on the right track, however it is not quite clear if you fully understand the concepts. The examples are not complete, check out page 5. The first example does not show circular reasoning and in the second example, pursue what? Using examples is a great way to convey ideas, just make sure they are complete and get your message across.

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specific aspect of the answer (e.g. original examples, writing answer in own words), directive information (e.g. information or page numbers), and comments on the detail and understanding in the answer. Examples of substantive feedback are shown Table 1.

Two assessors analyzed the feedback on the unit tests. A total of 376 tests were analyzed, each containing three questions. Interobserver reliability was assessed on the basis of the first student's unit tests prior to examining the unit tests of the other students. Agreement about the form of the feedback (substantive versus non-substantive) on these tests was 97%, and both assessors came to 100% agreement prior to carrying out the assessment on the remaining unit tests. After all analyses were independently carried out, one assessor randomly and independently analyzed 10% of the other assessor's unit tests. Agreement on these tests was 100%.

## 2. Results

Table 2 shows the total instances of substantive feedback on unit tests received by each student from other students, from the teaching assistant, from the instructor, and from all sources combined.

Table 2  
Substantive feedback units given and received in the course

Students	Total	Units of substantive feedback		
		From instructor/Teaching assistant	From other students	To other students
1	100	1	99	2
2	69	12	57	43
3	66	2	64	20
4	57	3	54	25
5	56	2	54	23
6	45	20	25	48
7	46	18	28	68
8	42	7	35	42
9	40	9	31	40
10	39	0	39	3
11	38	27	11	28
12	36	29	7	32
13	35	0	35	45
14	35	0	35	4
15	34	0	34	73
16	33	3	30	47
17	30	0	30	31
18	29	7	22	7
19	28	0	28	77
20	28	4	24	28
21	25	0	25	32
22	23	15	8	75
23	19	0	19	1
Totals	953	159	794	794

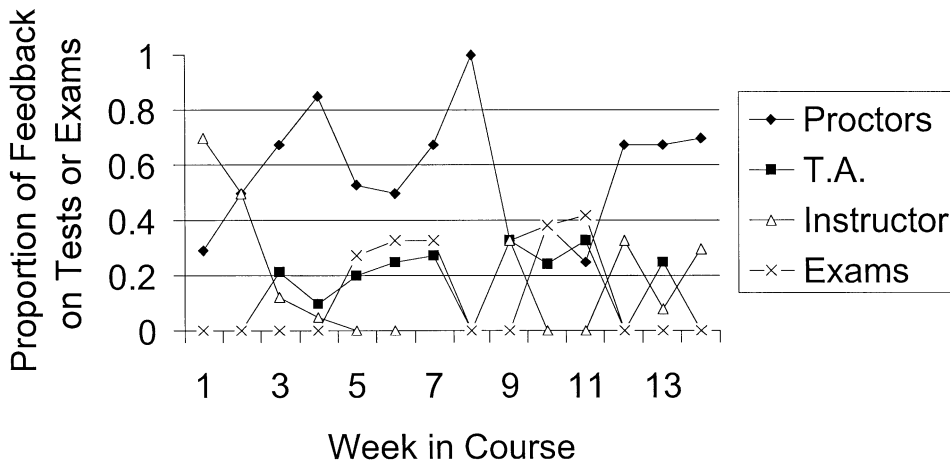


Fig. 2. The proportion of feedback provided by proctors, the teaching assistant, or the instructor on unit tests by week in course. In addition, the proportion of feedback provided on examinations (by both the instructor and teaching assistant) is included to show all of the feedback provided on various course work during the term.

The table also shows the total amount of feedback each student provided. Note that the lowest amount of substantive feedback any student received on unit tests was 19 instances. The median amount was 36 and the maximum was 100.

Fig. 2 shows that the instructor and teaching assistant provided the majority of feedback on unit tests during the first few weeks of the course. As the course continued the instructor and teaching assistant continued to provide feedback to the first few students who completed each unit and the instructor provided all of the feedback on the midterm and final examinations. However, proctors provided more of the feedback on unit tests.

### 3. Discussion

CAPSI is consistent with social constructivism in that feedback comes from another person. This other person may, of course, be the instructor or a teaching assistant. However, a test may also be sent to other students in the course who have passed the unit the test was on. In principle, the test could be sent to any number of students. So far, as in this study, we have simply had two students, randomly selected from those available, to mark and give feedback on another student's unit test. In order for the computer to consider the test to be a pass, both student markers must give it a pass. With this method, as the data show, students receive far more substantive feedback than would be possible in a traditionally taught course. The high amount of feedback coupled with the low amount of instructor monitoring makes (in our view) this procedure consistent with social constructivism. The knowledge built, or constructed, by students in this course develops in a manner that is not highly controlled by any one person, including the instructor; rather, it develops as a function of many transactions with many others in the learning situation.

It should be noted that the amount of feedback provided to, and received by, students is related to the number of unit tests written by each student; that is, the higher the number of unit tests



written, the greater the opportunity for both students and the instructor or teaching assistant to provide feedback. Also, the more units tests that a student completes, the more opportunities he or she has for providing feedback to other students.

It will be noted that in this study we did not address the accuracy of the feedback. This reflects the fact that, except when students appealed restudy results, accuracy of proctor feedback on unit tests is not a major focus—especially from a social constructivist point of view. It would be quite feasible to impose very strict criteria on what constitutes a pass and provide strong consequences to proctors for the feedback they provide. Answer keys could also be provided. However, we have thus far given a great deal of leeway to the individual judgments of the student markers. As indicated by the typical examples of proctor feedback in Table 1, students receive a great deal of conscientious substantive feedback from other students without these measures being taken. Thus, in a very real sense, this method provides an environment in which knowledge of the course material is constructed socially.

Naturally, the instructor is ultimately responsible for all the feedback in a course. However, having students who are slightly ahead of others give some of the course feedback is a common and useful pedagogical procedure. With advanced technology, such as used in CAPSI-taught courses, it is possible to implement this practice in a much more systematic way than was previously the case. This approach is highly compatible with social constructivism, which, as we have seen, maintains that learning (i.e. knowledge construction) ideally is the product of the interactions between individuals within a social situation.

Note how the CAPSI method is similar to the two models of social constructivist learning mentioned in the introduction: learning one's native language and advancing scientific knowledge. Students writing unit tests are analogous to a child learning to speak. In a particular context (a specific question or problem for the student) the student must emit verbal behavior that is clearly understood by a sample of other students as being relevant, accurate, and cogent. From the feedback the student receives, his or her verbal behavior with respect to the subject of the question is modified. As a result of many instances of this kind, the student's verbal behavior with respect to the course is modified in a way that is indicative of having learned the course material. Students writing unit tests are also analogous to scientists submitting articles for publication. The student markers correspond to the peer reviewers that journal editors send manuscripts to. The student's behavior with regard to studying for, writing, and submitting tests is modified in a way that is analogous to the modification of a scientist's research, writing, and arguments as a function of the peer reviewers of his or her manuscripts. Students who mark other student's tests in a CAPSI-taught course are peer reviewers. Their judgment that a test demonstrates mastery is analogous to recommending acceptance of an article for publication; their judgment that a test does not demonstrate mastery is analogous to rejecting the article. Of course, if a student disagrees with the markers he or she may appeal to the instructor. Similarly, an author who disagrees with the rejection of a manuscript may appeal to the editor or submit it elsewhere. As is the case with science, the process shapes everyone's learning. At its essence the process is social, and CAPSI encapsulates key features of this social process.

The effect of this teaching method on the student markers should also be noted. Being called upon to evaluate other students' answers in writing, student markers engage in the highest level of thinking (evaluation) in Bloom's (1956) taxonomy. In many cases student markers see answers that they had not thought of themselves, but that they recognize as good answers. They also see

answers that they recognize as incorrect but must learn to discern why they are incorrect. In view of these considerations, it should come as no surprise that students frequently cite being markers as the feature of CAPSI that taught them the most.

Social constructivists tend to shun the absolutes that are all too common in other teaching methods. That is, they recognize that often there is no one correct answer that demonstrates constructed knowledge. This viewpoint is built into the appeal procedure within CAPSI. A student who does not pass a test may compose an appeal of this result to the instructor. In order for the appeal to be successful, the student must make a valid argument showing why the test should have received a pass. Part of this involves carefully addressing and refuting points made by the marker(s). Thus, the appeal process also teaches evaluation both to the student making the appeal, and to the marker(s) who also see the appeal and the instructor's feedback on the appeal.

The CAPSI teaching method is highly flexible in that it may be modified and combined with other methods. We have used it in conjunction with other tools, such as lectures, discussion groups, website postings, and multimedia presentations. These tools often do not facilitate the types of interactions that social constructivism implies. As demonstrated in this article, CAPSI provides an electronic milieu in which social interactions consistent with social constructivism occur. Combining it with other tools may produce the best of all socially constructed educational worlds.

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