Distributed Learning Companion System : WEST Revisited

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Abstract. This paper describes a distributed learning system which consists of two connected computers so that students can learn in collaboration and/or competition at different locations. Considering different numbers and roles of involved agents, we have enumerated 768 possible distributed learning models. Among them, we evaluated 3 models using a system which is a re-implementation of the well-known WEST program. The evaluation result has two significant implications: (1) such learning systems hold the promise to be a form of futuristic intelligent computer classroom and (2) competition could be a powerful motive in learning that would shed new light on the Intelligent Tutoring System research.

1 Introduction

As pointed out by Gilmore and Self [17], de-emphasizing the role of computer as an authorized teacher for transmitting certified knowledge is the general trend of Intelligent Tutoring Systems (ITS). Self and his colleagues [11, 16, 17, 24, 25] suggested that the computer can be treated as a collaborator. Chan and Baskin [6, 7] proposed that computer can be simulated as two coexisting agents, a teacher and a companion, rather than the traditional single teacher oriented ITS. The two agents, the computer teacher and the computer companion, together with the human student, form a three agent learning model which is called the *Learning Companion System* (LCS). Moreover, the companion in an LCS can act as either a collaborator or a competitor at different learning stages. Chan [8] has reported an LCS prototype in the domain of integration calculus.

If the teacher's role steps aside in an ITS learning environment, then it will be crucial to investigate the various learning models based on different combinations of agent roles in the environment and their learning effects to students. Many advocates of learning environments with richer social context also argue that there are stronger learning motives in such environments. A chief factor for such motives is due to the competition, implicit or explicit, among peers. Thus, it is necessary to understand the role of competition in learning.

This paper describes a re-implementation of WEST which is a CAI classic developed for the PLATO Elementary Mathematics Project and ITS program [2, 3]. Our version is a distributed system in which two users can play concurrently at different locations and they play binary numbers instead of decimal numbers in the original WEST.

The system is implemented on IBM PC-compatible based on the consideration of its availability for field evaluation. At the topmost level of the system, it is a particularly designed knowledge-based authoring shell of ITS called *curriculum tree* [9] implemented using a small Lisp interpreter written in C. To link C procedures with the Lisp interpreter, we make use of a table of C procedures as the interface. C procedures are used to implement the lower-level modules due to its portability and ability of controlling hardware-dependent features. Finally, we use RS232 to connect two PCs for data communication. Sending and receiving messages are processed concurrently through an in-buffer and an out-buffer. Data is not packaged, characters are processed one at a time.

We also enumerate a huge number of possible distributed learning models. Among them, three models have been evaluated and their learning effects will be discussed in this paper. The contribution of this paper is that, based on our experience of realizing a distributed learning companion system, we offer more insights and a guideline for the design of future ITS as an alternative to one-on-one tutoring.

2 Background

Not at all is "peer learning" a new idea [19, 23]. In fact, peers teaching peers has long been a learning activity model in the classroom instructional design. As pointed out in [7], a wider view of LCS should not be limited to the three-agent model. The paradigm of LCS represents a broad spectrum of ITS design due to possible variations on the number and the identities of the agents in an LCS. As the price of computers is falling and the technology of computer network support is becoming more accessible, students are more likely to be able to learn together through geographically distributed networks of computers. Such systems are termed as *Distributed Learning Companion Systems* (DLCS). DLCS is a form of intelligent futuristic computer classroom. Students can learn at home with DLCS via communication with other students.

Psychological foundation of this research has been laid by various studies conducted on peer learning. In general, a peer who is at the same level of a student serves two possible roles for the student in learning: a collaborator and a competitor. As a collaborator, the peer provides cognitive conflicts and scaffolding. Piaget [22] suggested that peer exchanges, especially those that bring different viewpoints into the child's awareness, are likely to play a role in the reduction of egocentrism. Piaget regarded that the significance of peer interaction is the opportunity it offers to children to experience conflicts. He regarded the internal state of disequilibrium as the most important factor in cognitive development. Therefore, it is the active resolution of the cognitive conflict on the learner's part that accounts for the improved learning under the influence of social interaction.

A prominent viewpoint that complements Piaget's emphasis on disequilibrium is Vygotsky's [26] *zone of proximal development*. It refers to the distance between the actual developmental level as determined by independent problem solving and the potential development level as determined through problem solving under adult guidance or in collaboration with more capable peers. This hypothesis on emphasizing that social interactions playing a fundamental role in shaping internal cognitive structures has stimulated several developmentalists to examine aspects of peer learning interaction that are complementary rather than conflictual. The concept of *scaffolding* [4] captures the contribution a child (or an adult) can make to another child's learning by observing his or her behavior in providing hints, guidance, or advice, as well as feedback, correction, or evaluation. Scaffolding involves a kind of cooperative problem solving effort by both learners.

As a competitor, the peer is a source of motivation. It is certainly desirable for a learning environment to be able to enhance a student's achievement-striving behavior. Motivation, a factor to determine whether the student *will* do, not just whether he/she *can* do, is usually distinguished into two kinds: *extrinsic* and *intrinsic* motivation. A participant is extrinsically motivated if he/she is involved in an activity that will receive an apparent reward ; otherwise, he/she is intrinsically motivated [14]. Extrinsic motivation should not be encouraged, for a person's intrinsic motivation in the subject will decrease under extrinsic reward [12, 20].

There are two approaches in psychology to describing intrinsic motivation. The first is in terms of incongruity. Organisms are seen as needing to encounter stimulus events that are moderately discrepant from their accustomed stimulation. That is, the organism is intrinsically motivated by a need to encounter a moderate difference between his experience and his environment [1, 15, 18, 27]. The second approach focuses on the need and the capacity of organisms to deal effectively with the surrounding environment. Woodworth [29] believed that behavior was generally aimed at producing an effect on the environment; while White [28] emphasized the importance of a person's interaction with his/her environment. For White, intrinsic motivation was seen as the innate need to feel competent. Competence is described by Deci [13] as one's ability or capacity to deal effectively with one's surroundings. Activities like exploration, manipulation, attention, perception, thought, and communication are necessary for one to enable himself/herself to act effectively in his/her environment.

According to both of these two approaches, a learning environment with peers will promote intrinsic motivation to a learner. No matter whether it is in collaboration or competition, the mere existence of a learning companion may constantly stimulate the moderate difference described in the first approach, which, in turn, arouses the student's innate need of competence described in the second approach.

Competition is a social comparison process which involves individuals comparing their performance with some standard in the presence of other individuals who can evaluate the comparison process [21]. Competition will force a student to evaluate his ability in relation to the ability of the opponent. This competence information affects a student's intrinsic motivation through a change of perception of competence. High competence information leads to higher intrinsic motivation while lower competence information results in lower intrinsic motivation [5]. In particular, Collins and his colleagues [10] have presented a number of possible ill effects in learning. For example, some students are inhibited rather than motivated by competitive situations. Some people feel that competition encourages behavior and attitudes that are socially undesirable. Collins et al. suspect that some of these ill effects of competition have to do with attitudes toward and beliefs about errors. If students believe that making errors or being wrong about some process makes them "dumb," then comparative, competitive situations will be profoundly discouraging to weaker students. Another factor that makes competition seem problematic is that, under many forms of teaching, students lack the means for improving their performance.

3 Enumeration of Learning Models

There are many possible models of learning in distributed WEST system based on different combinations of agents and dimensions of factors such as roles, number, and levels of the agents. An agent in DLCS can be either a human or a computer, and a human agent can be a student or a teacher. Also, for a computer agent, it can be a computer companion or a computer teacher. Thus, a human student and a computer companion can both be the companion of another human student whereas a human teacher or a computer teacher can be his teacher. To limit our consideration, we assume that there exist two computers, each computer plays the role of at most one teacher and one computer companion, and no human teacher.

A computer teacher, if exists, can be a tutor, a coach, a critic, or an evaluator. A tutor is responsible for teaching and monitoring all parts of learning activities. A coach offers opinions, hints, advices, and strategies. A critic makes comments and opinions on a student's move. An evaluator simply evaluates the student's move and shows it to the student. Theoretically, these four different kinds of teacher may coexist at the same system. Students can select one or all of them to interact with during learning. An evaluator is non-adaptive while a tutor, a coach, or a critic can be either adaptive (sensitive to the student's learning history) or non-adaptive.

A computer companion, if exists, can be a collaborator or a competitor of the human student. WEST is a competitive game by nature. If the human companion is a collaborator, then the computer companion must be his opponent, and vice versa. But, when the human students collaborate, the two computers are perceived as the same competitor; while when they compete, the computers represent two different collaborators. Also, performance level of a computer companion is also a factor that have to be considered.

In one-to-one learning format, that is, two human students are learning companions through distributed network of computers, they can discuss problems collaboratively, compete with each other, one working on the problem and the other watching, or one to decide and the other to execute. Group-to-group learning is similar to one-to-one learning except that each group of human students can discuss before taking any action.

Levels and relationships of students may also affect students' learning. Some students prefer learning with more advanced students for more challenge and being able to learn from better performance, and some do not prefer doing so for avoiding pressure and being nervous. Likewise, some students would like to place themselves out of sight of their learning companions or do not want their companions to know who they are, because they may feel humiliated for their faults or slow response. Considering all of these factors that may affect the learning result, there are 768 models which is the size of the Cartesian product of those dimensions (not orthogonal) of factors as shown in Fig. 1.

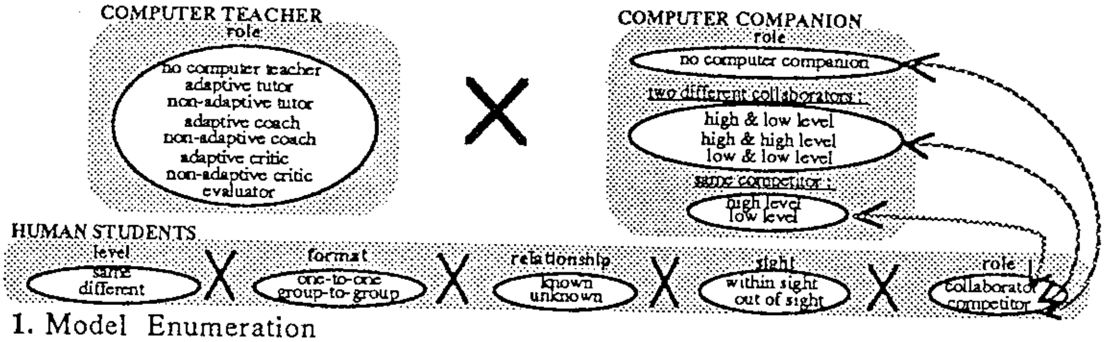
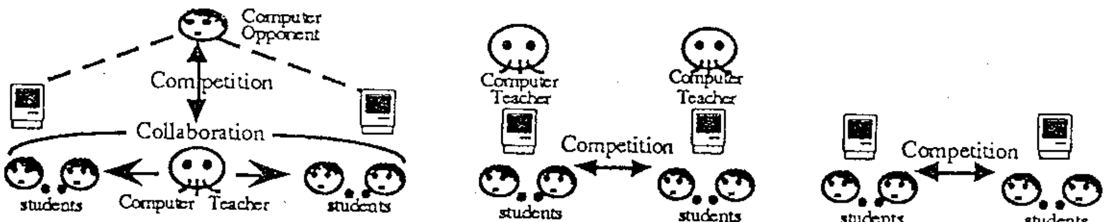


Fig. 1. Model Enumeration

4 Preliminary Field Evaluation

In our current version of the distributed WEST, there is only one computer teacher who is a non-adaptive coach. Since the name "coach" may allude to a strong persona to the student, the coach is called an evaluator in the system. Because of shortage of computers, we adopt a group-to-group learning format in our evaluation. We do not distinguish students by their levels for determining the level per se is a very difficult problem. Also, students are known to each other and they can see others during learning. We shall refer the human students playing on the other computer as "companion" or "learning companion".

Models Under the constraints mentioned above, we choose three rather typical models to evaluate. Model 1 (Fig. 2a) is collaboration between two groups of students. In this model, one offers opinion and the other makes a move after agreement with his collaborator. The system will be in a pending state until a consensus is reached. Model 2 (Fig. 2b) is competition between two groups of students. The coach on each side gives assistance. Model 3 is again a competition model (Fig. 2c), but no teacher is involved. Note that two models of competition among human students are chosen for there has been less work studying learning under competition.



a. Collaboration b. Competition c. No teacher

Fig. 2. Learning Models

Subjects There are 76 subjects who are students taking "Introduction to Computer Science" course in the National Taiwan Normal University, majoring in fields other than computer science.

Procedure Prior to the field evaluation, the student subjects are told that the transformation between the binary numbers and the decimal numbers as well as the binary number operations would not be taught in the classroom, and that they had to learn them through computer (binary number system is not part of Taiwan high school curriculum). After a brief explanation of the difference between the binary system and the decimal system, we asked students to sit in front of two connected PC, then 2 to 4 students are randomly grouped on each side of a DLCS. There are totally 32 groups. Following our explanation of how to enter DLCS environment and some rules of the game, we left the students to play the game themselves. Having finished the game, every student was asked to fill out a questionnaire. The questionnaire contains questions related to DLCS system and the binary number operations. 50 out of the 76 questionnaires we received are valid.

Result Summary

(1) For the question that asks about whether the student thinks that it is efficient to learn with a companion, 47 (94%) subjects responded affirmatively and that only 3 came up with a negative response.

(2) For those affirmative response, the effect of the learning companion they thought, in the order of importance, are:

(i) "I learn to think over problems more profoundly through discussion and brainstorming."; (ii) "Working with another person promotes their interest in learning."; (iii) "I can learn from my companion's strong point through observing his/her reactions."

(3) Most subjects (30) showed that they did not seem to care whether their companion was better or worse than themselves.

(4) 21 subjects prefer Model 2 (Competition), 16 prefer Model 3 (No Evaluator), and 13 prefer Model 1 (Collaboration).

(5) Reason(s) for the suitability and the unsuitability of the 3 models, in the order of importance, are:

Model 1 (Collaboration)

suitability: (i) "I learn to think over problems more deeply through discussion and brainstorming."; (ii) "Working with another person promotes my interest in learning."

unsuitability: (i) "It's less exciting without competition."; (ii) "Collaboration will result in discrepancies of opinions."

Model 2 (Competition with Evaluator)

suitability: (i) "It's competitive and thus more exciting."; (ii) "It's possible to learn to think more deeply through the help of an evaluator."

unsuitability: (i) "With the help of an evaluator, it is impossible to compete fairly."; (ii) "With the help of an evaluator, it is impossible to learn at my own will."

Model 3 (Competition without Evaluator)

suitability: (i) "Without an evaluator, it is possible to learn at my own will."; (ii) "Without an evaluator, it is possible to compete fairly."

unsuitability: (i) "Without the help of an evaluator, it is hard to find out my defects."

(6) Most subjects regarded learning binary number with such a system is effective.

5 Discussions

By no means our evaluation of the distributed WEST is extensive and vigorous. In the sequel evaluation, differences between cultural, sex, age, etc., as well as task performance analysis should be included. Given the vast number (768) of possible models of the DLCS system, how to choose significant models to be evaluated as well as to relate models to students' learning stages will be a challenge. In fact, we plan to evaluate the system systematically by possibly adopting a method called 'model elimination' in order to reduce the number of models to be evaluated through a sequence of evaluations. First, we begin with choosing some less important factor (such as whether students know each other), then we would fix other factors by picking one choice in each of those factors.

Then we would evaluate the models by varying choices of that factor and decide the best choice of that factor from the evaluation. In the subsequent evaluations, that factor will be fixed with the best choice found. As reported in this paper, we have evaluated only 3 models and did not include the important one-to-one learning model. Nevertheless, the preliminary impression of the learning effects of DLCS is promising and encouraging. Most significantly, there are two implications to the ITS research in general:

Firstly, for a long time, ITS research has been directed to the adaptivity to a student such as student modeling and dynamic course planning, etc., while initiatives or motives of a student that determine whether he will learn has not been seriously studied. Encouraged by the positive result of the distributed WEST, we feel that more research work ought to be focused on investigating alternatives to one-on-one tutoring. In particular, architecture design for such new learning environments poses a challenge to the ITS community.

Secondly, students seem to prefer competition (Model 2 and Model 3) to collaboration (Model 1). Indeed, from the experience of Integration-Kid, we suspect that the design and implementation of the competition mode may be simpler than the collaboration mode. Moreover, in Model 1, collaboration will not work when students are unwilling to hear dissenting voice. But, while competition provides a powerful motivator and organizer of learning as well as a strong focus for students' attention and improvement, among CAI and ITS communities, there is a phobia of competition. This phobia seems to be the extrapolation of the social blame that competition has been a means of distributing educational resources to the young; for example, using public examinations to screen students. Contrary to this pessimistic attitude, ITS research should not ignore the invaluable learning motives and striving attitude engendered by competition and try to avoid the ill effects, probably by nurturing collaboration simultaneously, caused by revealing strengths and weaknesses in comparison. Learning quality under a competition environment, perhaps, in accordance with Darwinian evolution theory, elevates.

References

1. D. E. Berlyne: Curiosity and learning. Motivation and Emotion, Vol. 2, pp. 97-175, 1978
2. R. R. Burton, J. S. Brown: A tutoring and student modeling paradigm for gaming environments. In Colman, R., & Lorton, P. Jr. (Eds.), Computer Science and Education, ACM SIGCSE Bulletin, Vol. 8, no. 1, pp. 236-246, 1976
3. R. Burton, J. S. Brown: An investigation of computer coaching for informal learning activities. International Journal of Man-Machine Studies, Vol. 11, pp. 5-24, 1979
4. J. S. Bruner: The ontogenesis of speech acts. Journal of Child Language, Vol. 2, 1975
5. A. T. Byrne: The effect of competition on intrinsic motivation. Master Thesis, Department of Physical Education, University of Illinois at Urbana-Champaign, 1984
6. T. W. Chan, A. B. Baskin: Studying with the Prince : The computer as a learning Companion. International Conference of Intelligent Tutoring Systems, 1988, June, Montreal, Canada, pp.194-200, 1988
7. T. W. Chan, A. Baskin: Learning Companion Systems. In C. Frasser & G. Gauthier (Eds.) Intelligent Tutoring Systems: At the Crossroads of Artificial Intelligence and Education, Chapter 1, New Jersey: Ablex Publishing Corporation, 1990
8. T. W. Chan: Integration-Kid: A Learning Companion System. The 12th International Joint Conference on Artificial Intelligence, Sydney, Australia, Morgan Kaufmann Publishers, Inc., pp. 1094-1099, 1991

9. T. W. Chan: Curriculum Tree: A Knowledge-Based Architecture for Intelligent Tutoring Systems, to be appeared in Second International Conference of Intelligent Tutoring Systems, 1992, June, Montreal, Canada, 1992
10. A. Collins, J. S. Brown, S. E. Newman: Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser, Hillsdale, NJ: Lawrence Erlbaum Associates Publishers, 1989
11. G. Cumming, J. Self: Collaborative Intelligent Educational Systems. In D. Bierman, J. Breuker, & J. Sandberg (Eds.), Artificial Intelligence and Education, pp. 73-80, Amsterdam: IOS, 1990
12. E. L. Deci: Effects of externally mediated rewards on intrinsic motivation. Journal of Personality and Social Psychology, Vol. 18, pp. 105-115, 1971
13. E. L. Deci: Intrinsic motivation. New York: Plenum, 1975
14. E. L. Deci: Intrinsic motivation: Theory and application. In D. M. Landers & R. W. Christina (Eds.), Psychology of motor behavior and sport, pp. 338-396, Champaign, IL: Human Kinetics, 1978
15. W. N. Dember, R. W. Earl: Analysis of exploratory, manipulatory, and curiosity behaviors. Psychological Review, Vol. 64, pp. 91-96, 1957
16. P. Dillenbourg, J. Self: Designing Human-Computer Collaborative Learning. In C. O'Malley (Ed.), Human-Computer Collaborative Learning, Springer-Verlag, 1991
17. D. Gilmore, J. Self: The application of machine learning to intelligent tutoring systems. In J. Self, (Ed.) Artificial Intelligence and Human Learning, Intelligent computer-assisted instruction, pp. 179-196, New York: Chapman and Hall, 1988
18. J. McV. Hunt: Intrinsic motivation and its role in psychological development. Nebraska Symposium on Motivation, Vol. 13, pp. 189-282, 1965
19. E. Hutchins: The technology of team navigation. In J. Galegher, R. Kraut, & C. Egido (Eds.), Intellectual Teamwork: Social and Technical Bases of Cooperative Work. Hillsdale, NJ: Lawrence Erlbaum Associates Publishers, 1990
20. M. R. Lepper, D. Greene, R. E. Nisbett: Undermining children's intrinsic interest with extrinsic rewards: A test of the "overjustification" hypothesis. Journal of Personality and Social Psychology, Vol. 28, pp. 129-137, 1976
21. R. Martens: Competition: In need of a theory. In D. M. Landers (Ed.), Social Problems in Athletics, pp. 9-14, Urbana, IL: University of Illinois Press, 1976
22. J. Piaget: The moral judgment of the child. New York: The Free Press, 1965
23. L. B. Resnick: Constructing knowledge in school. In L. S. Liben (Ed.), Developmental learning: conflict or congruence. Hillsdale, N. J.: Erlbaum, 1989
24. J. Self: A perspective on intelligent computer-assisted learning. Journal of Computer Assisted Learning, Vol. 1, pp. 159-166, 1985
25. J. Self: The application of machine learning to student modelling. Instructional Science, Vol. 14, pp. 327-338, 1986
26. L. Vygotsky: Mind in society . (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Trans.) Cambridge, MA: Harvard University Press, 1978
27. E. L. Walker: Psychological complexity as a basis for a theory of motivation and choice. Nebraska Symposium on Motivation, Vol. 13, pp. 47-95, 1964
28. R. W. White: Motivation reconsidered: The concept of competence. Psychological Review, Vol. 66, pp. 297-333, 1959
29. R. S. Woodworth: Dynamic psychology. New York: Columbia University Press, 1918