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Distributed Problem Solving: The Social Contexts of Learning and Transfer

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ABSTRACT

The problem of transfer remains one of the most difficult challenges for schooling: knowledge and skills that students learn in a classroom is often not used in out-of-school contexts. To address this problem, this paper analyzes educational interaction conducted via long-distance electronic networks. We present a new methodology, called Semantic Trace Analysis. From our analyses, we present two possible solutions to the transfer problem. First, we describe an organizing framework for network interactions, which we call "receiver site transfer", which provides a functional environment for students' problem solving. In addition, we describe some initial explorations of "teleapprenticeships", instructional interactions through which students learn knowledge and skills by interacting with adults outside the school system. To the extent that adults increasingly use electronic networks for their work, we will be able to avoid the transfer problem by instructing students within the same context that they will use that instruction.

INTRODUCTION

Studies of problem solving have pointed to the problematic nature of transfer (Reed, Ernst & Banerji, 1974; Gick & Holyoak, 1980). Cognitive skills learned in one task are generally not used by subjects in "isomorphic" tasks (tasks perceived by the experimenters to be "the same task"). These experimental findings reinforce the widely expressed concern about the lack of transfer of skills and knowledge learned in school to out-of-school settings.

Pea (1987) has pointed to the limitations of locating the transfer problem solely in the task and the individual, and has suggested ways in which the social context is important in determining perceived similarity of problems and in selecting and applying previously learned skills to a novel problem. He draws upon a "cultural practices" theory (Laboratory of Comparative Human Cognition, 1983) for determining how skills will or will not be transferred.

We feel that this focus on the social context of problem solving, while an important first step, does not go far enough. The experimental findings described previously can be summarized crudely as

"Subjects will transfer skills and knowledge to a new task only when you tell them to transfer." This is somehow seen by the experimenters as a shortcoming of the subjects. If we view the experimental situation as an instructional one, we could instead blame the experimenters as inferior teachers, or blame the "educational system." However, viewed from the point of view of the subjects/students, transferring when being told to transfer is generally a very effective strategy, since the social context for most problem solving (both school-based and non-school-based) typically provides this sort of cueing support. Real problem solvers are often "told" by the social context what sort of problem they are facing and what sort of solution strategy might be appropriate.

The rationale for focussing on the "individual invention" aspect of transfer is so that problem solvers are not locked into a set of viewpoints suggested by a specific social context. In this way, innovative solutions can be reached. However, rather than focussing entirely on individual cognitive skills, a theory of transfer that takes social context into account needs to focus on ways that the naturally occurring *diversity* of social contexts which are available provides a more powerful means to suggest to problem solvers diverse, creative solutions for problems. We have developed one such model of the acquisition of transferrable skills, which we call *receiver site transfer.*

RECEIVER SITE TRANSFER

In our previous studies of instruction on electronic networks, we have developed a model of transfer, which we call "receiver site transfer" (Levin, Riel, Miyake, & Cohen, 1987; Levin, Waugh, & Kolopanis, 1988; Waugh & Levin, 1988; Waugh, Miyake, Levin & Cohen, 1988). It arose out of a goal to have students learn problem solving by tackling "real" problems (problems faced by the adults in the students' community), rather than by solving puzzles or other such problem solving exercises. The dilemma we faced was that "real" problems are *really* difficult and most often have no agreed-upon solution (otherwise they wouldn't still be problems for the adults in the community). We were concerned that conventional approaches to problem solving instruction when applied to such difficult problems would lead to frustration on the learner's part, and instead only teach them that they shouldn't try to solve real problems. Motivated by the theory of "dynamic support" (Riel, Levin, & Miller-Souviney, 1987), we considered how we might use other students, teachers, and adults linked to the students by electronic networks as a dynamically changing source of support for students' problem solving efforts.

For example, a shared "real" problem for a number of sites is a shortage of drinking water. A conventional approach to problem solving and instruction might have the students gather information about the problem, "brainstorm" ideas, and then evaluate their ideas (Polya, 1957). With this approach, most students would be unlikely to develop practical alternative solutions which passed even a superficial evaluation.

Instead, we took a "receiver site transfer" approach: 1) students in different geographic locations each described the ways that the problem is dealt with (partially) in their own location, 2) these descriptions were sent to the other participating locations, 3) students then analyzed the descriptions from the other locations, comparing them to their own descriptions, and 4) for those used elsewhere but not in their own location, students were asked to determine whether those techniques could in fact be applied in their own location. Thus, the diversity of sites served as a major source of potentially transferrable solutions to the problem.

We call this "receiver site transfer" because of its contrast to the usual form of advice giving in problem solving. Often when people have problems, they call upon an expert to tell them how to solve the problems. Typically an expert recommends that they use the way that a problem is solved in the expert's own location. We call this "sender site transfer", since the "transfer" is being carried out by the person from the place where the knowledge or skill originated.

In the case of "receiver site transfer", the individuals with a problem actively seek out others who have the same problem, and solicit from them descriptions of how they solve the "same" problem. Thus, the initiative for the transfer comes from the "receiving" site. Those seeking advice then try to determine which techniques are shared in common, and which are used elsewhere but not locally. The receiving site people are in a good position to examine specific differences between the two locations that might make a solution used elsewhere less useful locally. They may find relatively simple modifications to a solution used elsewhere that would make it useful locally. Or a given solution may suggest (through analogy or through similarity) other approaches that might work locally. The "receiver site transfer" model provides support for problem solving transfer that makes the problem solvers active participants in the generation of solutions, rather than passive receivers of "pat" solutions developed by "experts" elsewhere.

Levin, Kim and Riel (1988) found that the nature of the instructional interaction among students involved in electronic networking is different than that exhibited by students engaged in typical classroom instruction. Similarly, we have found that the nature of students' problem solving efforts in this medium are also quite different than typical classroom-based problem solving efforts of students. Electronic networks provide a medium which is qualitatively superior to the traditional classroom for helping students transfer practical problem solving skills and knowledge to new content domains.

THE WATER PROBLEM SOLVING PROJECT

The analyses of the problem solving activity discussed in this paper concern a project known as the *Water Problem Solving Project* (Levin & Cohen, 1985) which was conducted on a network called the InterCultural Learning Network. In this project, students in the United States, Mexico, Japan and Israel jointly tackled the problem of shortages of drinking water. In the initial phase of the project, the students conducted research and developed a description of how drinking water was obtained in the area where they lived. Next, these student-generated descriptions were sent via the network to the other project participants, and each of the groups of students were asked to analyze the techniques contributed by the other groups for acquiring and distributing potable water in order to identify patterns of similarity and difference. For those techniques used in other sites but not their own, students were asked to determine *why* the techniques were not used locally. In the final phase of the project, the students were asked to collect any additional information needed and then to make a judgement on the feasibility of utilizing one or more of these different techniques to help solve the water problem in their own location. They wrote up a report of their research, and sent it on the network to the other participants. This phase we call "post problem solving publication".

Receiver site transfer involves students in the process of acquiring information from diverse sources concerning the solution of some problem which is common among the various locations. The students then analyze the information in order to identify how the information might be applied in their location and share their analyses with the other network participants. The primary advantages of receiver site transfer are the following: it enables students to work on "real world" problems; it requires students to clearly articulate their thoughts in writing; it is interactive; it embodies the concept of peer tutoring; it requires students to analyze facts and synthesize new ideas. In addition, the technique seems to be highly motivating. Using this technique the emphasis in the problem solving activity is shifted away from simple attempts to brainstorm possible new solutions for a local problem, and instead toward comparing and analyzing solutions employed in other locations to solve similar problems and then attempting to adapt those solutions to fit the local situation.

Through engaging in activities which embody the receiver site transfer technique, students gain experience in using a practical method for solving "real" problems. In addition, because this technique is readily applied to a wide variety of specific problems, students can experience using the same technique in numerous problem solving activities. The flexibility of the technique provides students with a ready mechanism for exploring multiple points of view concerning the nature of and solutions for specific types of "meaningful" problems.

SEMANTIC TRACE ANALYSIS

Miyake developed the Semantic Trace Analysis as a technique for analyzing the network-based student interactions because the other types of analyses which we had previously employed focussed very specifically on syntactic or quantitative characteristics of the students' messages. The Semantic Trace Analysis is an attempt to focus on the nature of the content of the student interactions. What content were the students experiencing during the interaction? What was the purpose of their communication? In order to answer these questions, we needed a method of tracing the pattern of the development of students' ideas over the course of their project-oriented discussions in order to identify what contributed to the growth of the activity.

We applied this technique to the message interactions which were generated in the *Water Problem Solving Project*. We began by constructing a collective overview, or framework, consisting of all the ideas which were contributed by the students and other related concepts that have been mentioned in the discussion of the problem of obtaining drinking water. On this framework, we traced the course of the development of the students' ideas and graphically represented that pattern in chart form (see Figure 1). Using the chart as an activity map, one can identify information such as where a particular part of the interaction arose, how it became integrated into the previous discussion, and how the focus of the discussion shifted as a result of a particular communication.

Our analysis of the activity map for the *Water Problem Solving Project* reveals the importance of involving diverse groups of network participants. Whether it is the diversity among the participants or the nature of the activity or these characteristics in combination with others, this network-based activity resulted in significant contributions to the problem solving activity from multiple points-of-view. Whether or not the contributions were made because the activity compelled them to occur, or because the natural differences among the participants made it easy for each participant to contribute a unique and interesting observation remains a subject for further study. However, bringing multiple points-of-view to bear in problem solving efforts is highly desirable (Miyake, 1986) yet the practical difficulty of providing for these multiple viewpoints in functional settings in "typical" educational practice is significant.

Another valuable attribute of the Semantic Trace Analysis is its ability to serve as an evaluation mechanism for a network-based problem solving activity. By using the Semantic Trace Analysis map of the Water Problem Solving Project (Figure 1), one can easily see how the large number of ideas contributed to the ongoing discussion. In comparing these data to the summary message generated from any given site, one can gain a better perception of the influence that the network activity has had upon the students in that location. For example, a class of 8th grade students at Lincoln School in San Diego, California participated in the Water Project and twenty of those students contributed a summary message in which the students mentioned 71% of the ideas for solutions to the water problem which had been contributed by all of the network participants from around the world. Among those ideas mentioned by the San Diego students, 66% had been

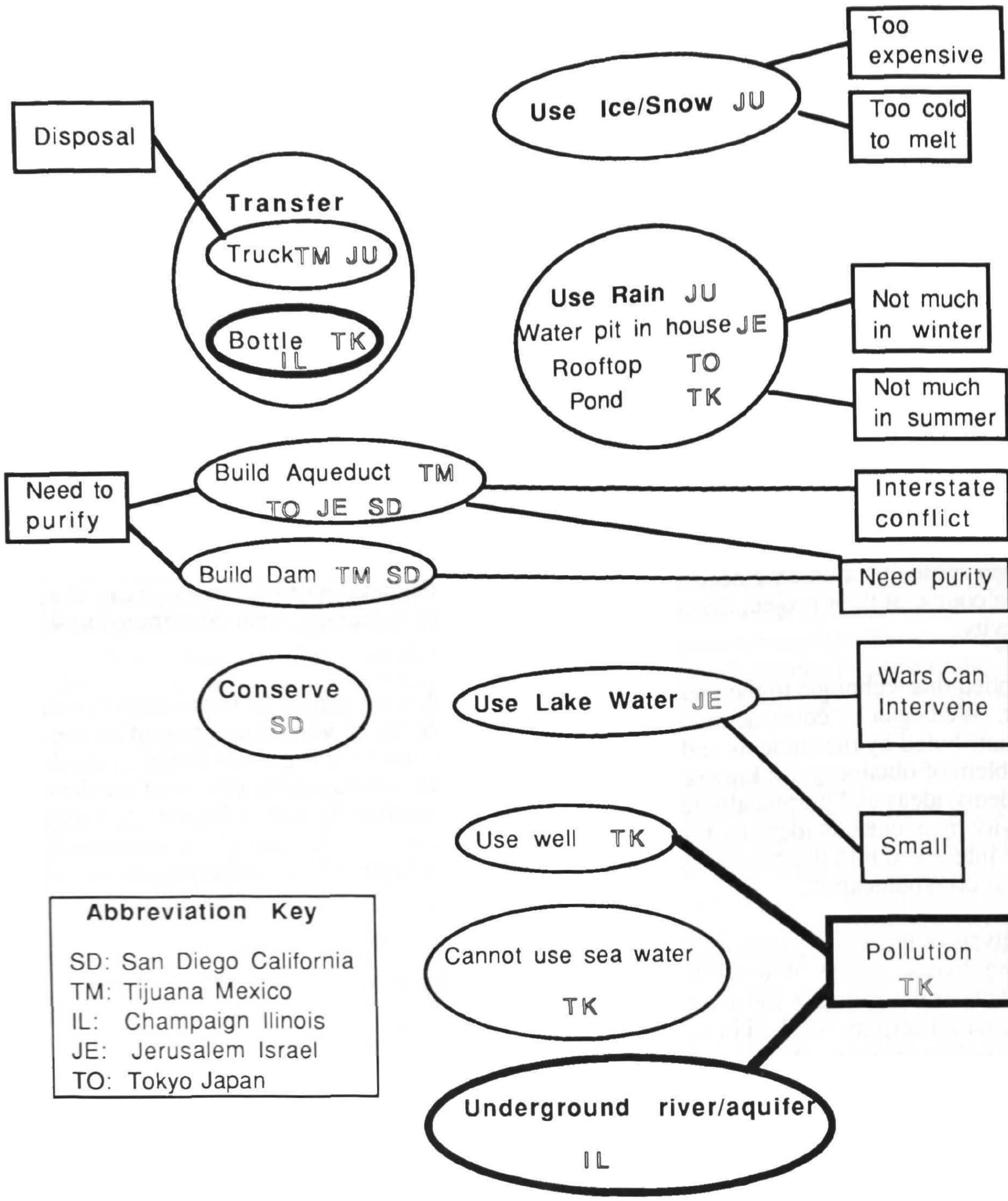

Figure 1: Semantic Trace Analysis of the Water Problem Solving Project

contributed by sites other than San Diego. Each student contributed between 0 and 4 ideas concerning techniques for water acquisition which might be used in the San Diego area. Almost half of the students (9 out of 19) contributed more than one idea on the topic (with an average of 1.7 ideas per student). Although these figures do not assess how much each individual student may have profited from the interaction among the network participants they do indicate a significant impact on the group as a whole.

TELEAPPRENTICESHIPS

We have observed a pattern in instructional electronic network interactions, teleapprenticeships, that resembles one found in traditional face-to-face apprenticeships. This pattern is characterized by a rich set of interactions between a diverse set of participants, a pattern quite different from that typically found in conventional classroom instruction (Levin, Riel, Miyake, & Cohen, 1987; Waugh, Miyake, Levin, & Cohen, 1988). Many of the recent research-based developments in instruction have been characterized as "cognitive apprenticeships" by Collins & Brown (Brown. Collins, & Duguid, 1989; Collins, 1988; Collins, Brown, & Newman, 1988). However, the instructional techniques described by Collins and Brown all take place within a conventional classroom. Telecommunications allows students within schools to interact with other students, teachers, and adults outside the school system in collaborative efforts to solve real, meaningful problems.

As more and more adults outside the school system begin using electronic message systems for their everyday work, we may see a new form of educational interaction evolve, in which students in schools spend more and more of their instructional time learning through their interactions with adults outside the schooling system. Students will learn in a functional learning environment by serving as "teleapprentices" to adults who are not professional teachers.

One of the major advantages of apprenticeship learning is that since skills and knowledge are learned in the same context in which they are to be used, the universal problem of "transfer" that afflicts all of schooling is minimized. If students acquire skills and knowledge in teleapprenticeships, then the problem of transfer is also minimized, since the context provided by the electronic network is the same context in which the skills and knowledge will be used.

Our analyses of instructional interactions on long-distance networks (Levin, Kim, & Riel, 1988; Waugh, Miyake, Levin, & Cohen, 1988) illustrate how such teleapprenticeship interactions can now be conducted. Since the interaction is in non-real time, it has become easier for both mentor and apprentice to participate, since they can control the time spent in the apprentice interaction. The network medium allows for a wider variety of people to interact than is typical of normal instructional settings.

SUMMARY

In this paper, we have presented a brief analysis of problem solving conducted via long-distance electronic networks. The analysis suggests two possible solutions to the transfer problem. The first solution is an organizing framework for network interactions, which we call "receiver site transfer". This framework provides a functional environment for students' problem solving, providing "dynamic support" for their efforts to tackle "real" problems. The second solution is "teleapprenticeships", instructional interactions through which students learn knowledge and skills by interacting with students, teachers and adults outside the school system. As adults increasingly use electronic networks for their work, we can avoid the transfer problem by instructing students within the same context that they will use what they learn.

REFERENCES

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher,* **18**, 32-42

Collins, A. (1988). Cognitive apprenticeship and instructional technology. Report No. 6899. Technical report. Cambridge, MA: Bolt, Beranek and Newman, Inc.

Collins, A., Brown, J. S., & Newman, S. E. (1989). 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: Erlbaum.

Gick, M., L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology,* **12**, 306-365.

Laboratory of Comparative Human Cognition (1983). Culture and cognitive development. In W. Kessen (Ed.), *Mussen's Handbook of child psychology (4th edn.), Vol. 1* (pp. 295-356). New York: Wiley.

Levin, J. A., & Cohen, M. (1985). The world as an international science laboratory: Electronic networks for science instruction and problem solving. *Journal of Computers in Mathematics and Science Teaching,* **4,** 33-35.

Levin, J. A., Kim, H., & Riel, M. M. (1988). Analysis of instructional electronic message interactions. Paper presented at the American Educational Research Association Meetings, New Orleans.

Levin, J. A., Riel, M., Miyake, N., & Cohen, M. (1987). Education on the electronic frontier: Teleapprentices in globally distributed educational contexts. *Contemporary Educational Psychology,* **12**, 254-260.

Levin, J. A., Waugh, M., & Kolopanis, G. (1988). Science instruction on global electronic networks. *Spectrum: The Journal of the Illinois Science Teachers Association,* **13**, 19-23.

Miyake, N. (1986) Constructive interaction and the iterative process of understanding. *Cognitive Science,* **10**, 151-178.

Pea, R. D. (1987). Socializing the knowledge transfer problem. *International Journal of Educational Research,* **11**, 639-663.

Polya, G. (1957). *How to solve it.* Garden City, New York: Doubleday-Anchor.

Reed, S. K., Ernst, G. W., & Banerji, R. (1974). The role of analogy in transfer between similar problem states. *Cognitive Psychology,* **6**, 436-450.

Riel, M. M., Levin, J. A., & Miller-Souviney, B. (1987). Learning with interactive media: Dynamic support for students and teachers. In R. W. Lawler & M. Yazdani (Eds.), *Artificial Intelligence and education: Learning environments and tutoring systems (Volume One).* Norwood, NJ: Ablex Publishing.

Waugh, M., & Levin, J. A. (1988). Telescience activities: Educational uses of electronic networks. *Journal of Computers in Mathematics and Science Teaching,* **8,** 29-33.

Waugh, M., Miyake, N., Levin, J. A., & Cohen, M. (1988). Analysis of problem solving interactions on electronic networks. Paper presented at the American Educational Research Association Meetings, New Orleans.