The Social Role of Technical Personnel in the Deployment of Intelligent Tutoring Systems

Ryan Shaun BAKER, Angela Z. WAGNER,
Albert T. CORBETT, Kenneth R. KOEDINGER
Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, PA 15213 USA
rsbaker, awagner, corbett, koedinger @cmu.edu
(+1) 412-897-8957

Most of the prior descriptions of the important relationships in Intelligent Tutoring System (ITS) projects have focused on students, teachers, tutoring systems, and tutoring system researchers. While these models may accurately describe how tutors have their educational effects, they bypass the question of how tutors become deployed into classrooms. Similarly, there has been discussion of how an Intelligent Tutor, once developed, can be disseminated widely [5], but less discussion of the deployment of prototype ITSs. In this paper, we discuss how field technical personnel can serve as vital conduits for information and negotiation between ITS researchers and school personnel such as teachers and principals. We do so via a case study, using the method of Contextual Inquiry [4], of a technical research assistant who has facilitated the links between our project and our partner schools.

This paper is the expanded version of a poster paper of the same name, which will be presented at the Intelligent Tutoring Systems Conference in August 2004.

Both versions of this paper are available off the first author's website.
This version is officially "unpublished".

1. Introduction

1.1 Overview

In recent years, Intelligent Tutoring Systems (ITSs) have emerged from the research laboratory and pilot research classrooms into widespread use [5]. Before one of our laboratory's ITSs reaches a point where it is ready for large-scale distribution, it goes through multiple cycles of iterative development in research classrooms. This process requires a great deal of collaboration and cooperation across several years from individuals at partner schools, from principals and assistant superintendents, to teachers, to school technical staff. In the first stage of tutor development, this process is supported by a teacher who both teaches the tutor class and participates in its design. In a second stage, the tutoring curriculum is deployed from the teacher-designer's classroom to further research classrooms, and refined based on feedback and data from those classrooms. Finally, a polished tutoring curriculum is disseminated in collaboration with our commercial partner, Carnegie Learning Inc.

In this paper, we discuss how the second stage of our process – the deployment of prototype ITSs to research classrooms -- is facilitated by the creation of working and social relationships between school personnel and project technical personnel. Specifically, we present a case study on a member of our research laboratory whose job is, at least in theory, primarily technical in nature. It would not be an exaggeration to say that this individual's efforts have been indispensable to the Pittsburgh Advanced Cognitive Tutor (PACT) Center's successful deployment of recent ITS research to middle schools and high schools (such as [1,2,6,9]).

We will discuss how this individual facilitates the links between our research laboratory and the schools we work with. We will illustrate her working relationships with teachers and support personnel at the schools, and her strategies for making these relationships function more effectively. Our findings suggest that even in an educational project built around technology, the human relationships supporting that technology are essential to the project's success. Understanding how such relationships can be built and maintained will be useful to the conception and setup of new large-scale educational technology projects, and will also be useful to developing training materials for individuals working as liaisons or technical support staff in educational technology research projects.

1.2 Rose

In this paper, we present a case study of Rose[1], a research assistant working with our project. Seven years ago, while still a college undergraduate, Rose began working as a research assistant for an educational research project in the Psychology Department at Carnegie Mellon University. After she graduated, four years ago, she took a job as a research assistant with our laboratory, the Pittsburgh Advanced Cognitive Tutoring (PACT) Center. Rose's position was initially primarily technical – her job description included writing tutor problems, testing tutoring software, installing tutoring software on school machines, developing immediate workarounds for bugs, collaborating with school technical staff in order to get software installed, collecting tutor log files, and administering tests to

[1] In order to protect confidentiality, pseudonyms are used for all individuals described in this paper.

students. The beginning of Rose's work with our laboratory coincided exactly with the first year of development of a new Intelligent Tutor curriculum for Middle School Mathematics. During this first year, Rose worked in collaboration with two other research assistants, supporting four school sites. Over the intervening years, the other two research assistants left our laboratory (both going to graduate school at other universities). Last year, as our project moved into the deployment stage, Rose fulfilled these roles at six school sites, as the sole individual in our laboratory doing so.

1.3 Methods

To develop an understanding of Rose's work practices, strategies, and important collaborative relationships, we conducted a set of retrospective contextual inquiries [4] on Rose. Contextual Inquiry (CI) is an interview method which differs substantially from traditional interview. Whereas in traditional interviews, the interviewer drives the interaction, asking often pre-determined questions, in a Contextual Inquiry the interview participant leads the interviewer through the process of completing a genuine task – the participant adopts the roles of a master teaching an apprentice (the interviewer). During the CI, the interviewer/participant pair alternate between working on the task and discussing interpretations of the participant's actions and their meaning within the participant's overall goal structure. By contrast to traditional interviews, which can occur in any setting, a contextual inquiry occurs in the participant's actual work context. In context, the participant's work process is most genuine, their memory best primed, and they have ready-at-hand access to artifacts which help explain their process.

Although it is preferable to conduct a contextual inquiry during the performance of the actual task, this is not possible in situations where the task is distributed over a substantial length of time. Since Rose's interactions with school personnel have taken place over the last four years, and relationships with specific teachers have lasted as long as three years, it was not possible to directly observe the entire course of these relationships. Accordingly, we conducted a retrospective contextual inquiry on Rose. Before the interviews, we asked Rose to collect the last several months of her history of emails with a specific set of teachers and school personnel. During the interview, she used these emails to lead us through her process of interaction with each of her collaborators.

After interviewing Rose, we conducted further interviews with researchers in our project, and with researchers and technical staff in other projects who support the deployment of ITSs into schools. Rose was able to help us compare and contrast the findings from these interviews with her process.

2. The Relationships in Intelligent Tutoring Projects

One of the keys to Rose's effectiveness is the central role she plays in the collaboration between our laboratory and the schools we work with. In order to discuss this, we will first briefly outline some prior models of the important roles in Intelligent Tutoring projects, and the relationships between those roles. We will advance a new model of the important roles and relationships in Intelligent Tutoring projects, and discuss how Rose and other individuals have filled these roles. Our model builds upon prior models of the important roles in Intelligent Tutoring projects, extending them to incorporate the relationships which facilitate the deployment of tutors into research classrooms. As with previous models, our model is not exhaustive – outside of the deployment stage discussed here, other stakeholders, such as parents and school district administrators, likely play a considerable role.

One early discussion of the important roles in intelligent tutoring projects appears in Wenger's *Artificial Intelligence and Intelligent Tutoring Systems* [13]. Wenger suggested that the central function of an Intelligent Tutoring System (ITS) is to serve as a conduit for the communication of knowledge between the tutor's creator(s) and the student. In large ITS projects, tutors are often created through a collaboration between designers/researchers and programmers. Based on Wenger's conception, this set of relationships could be modeled as shown in figure 1.

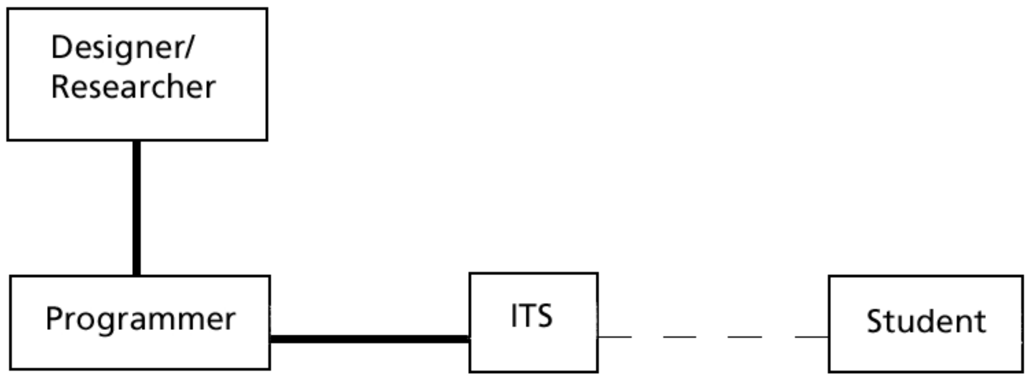

Figure 1: The relationships in Intelligent Tutoring Projects, discussed by Wenger.

Schofield suggested that ITSs also shape the interaction between the student and their teacher [11]. By observing students using the tutor and following the tutor's assessment of the students, teachers learn which students need the most help and exactly what steps the students are having the most trouble with. The teacher's role in an intelligent tutor classroom is essential; they deliver the conceptual instruction which the ITS builds upon, and provide one-on-one tutoring to the students who need it most. Such a model of the teacher's role is shown in Figure 2.

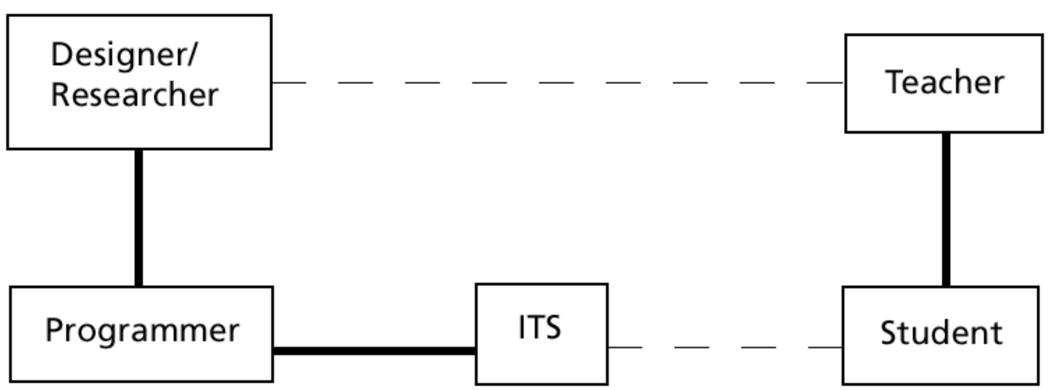

Figure 2: Schofield notes that teachers play a key role in classrooms with Intelligent Tutoring Systems.

But teachers have frequently played an even more significant role than this in the PACT Center's development of ITSs. While students are the users of the ITSs we develop, in a very real sense teachers and schools are our clients. Our tutors must fill a need in the teachers' classrooms and support them in instructing students more effectively. Since tutors must be used in real classrooms, it has been highly valuable to collaborate with skilled teachers who possess visceral and immediate understanding of how learning occurs "in the field". Thus, going back to our earliest projects developing intelligent tutors for high school mathematics classrooms, our laboratory has involved teachers as full collaborators in the process of designing our tutoring systems [5], in accordance with the philosophy of Participatory Design [7]. Such teachers develop tutoring curricula with us half-time, and continue to teach classes at their school the other half of the time.[2]

The model in Figure 2 could conceivably accommodate this additional role, by treating such a teacher as a designer/researcher who "happens to be a teacher too". Many of the teachers who have worked with our project during the first stage of development of a new tutoring curriculum have fulfilled exactly this role. One teacher fulfilled both this role and another role, which will be discussed later in this paper.

Beyond this, one limitation of the model in Figure 2 is that it does not take into account the issue of how ITSs are actually deployed and integrated into classrooms. Placing a tutor curriculum in a classroom requires authorization from school officials, persuading teachers to cooperate in the face of significant inconvenience (early versions of software often have error-producing bugs), installing the ITS on school machines, and making sure it works.

One model of how deployment takes place is that principals work with teachers and loosely communicate with researchers to discuss the ITS, and that installers and field technical staff from the research lab work closely with school technical support to install the software. In this view, shown in Figure 3, the main job of a research assistant working as a technical liaison would be to take the software written by the programmers, and work with the school technical support to install it and get it working on the school machines. A discussion with the director of another intelligent tutoring project confirmed that this agreed with his interpretation of what such research assistants do.

[2] During our participatory design process, the teachers' entire salary is paid for by the PACT Center, providing a compensating benefit to the school district.

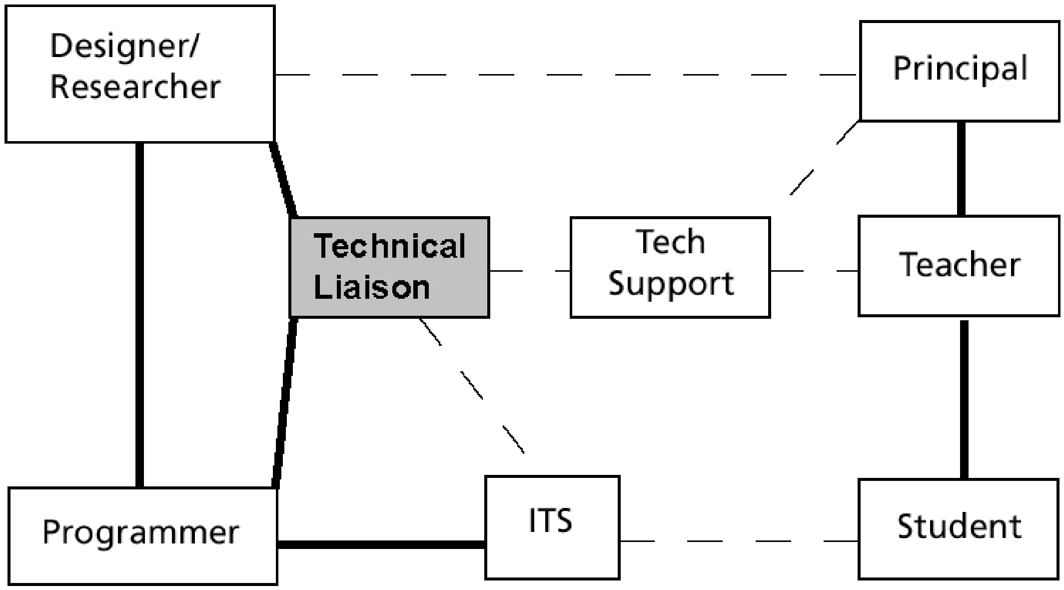

Figure 3: A common-sense model of a technical liaison's role in an Intelligent Tutoring project.

In practice, however, Rose's role has been quite different. Instead of primarily acting as a liaison between the project's programmers and the school's technical staff, she has primarily acted as a liaison between the project's designers and the school's teachers. By filling this alternate role, shown in Figure 4, Rose is not only more effective at installing and maintaining our software at the schools, but has also been able to assist our project in many other ways. In the following section, we will discuss Rose's strategies in more detail, as well as the opportunities they open for our project.

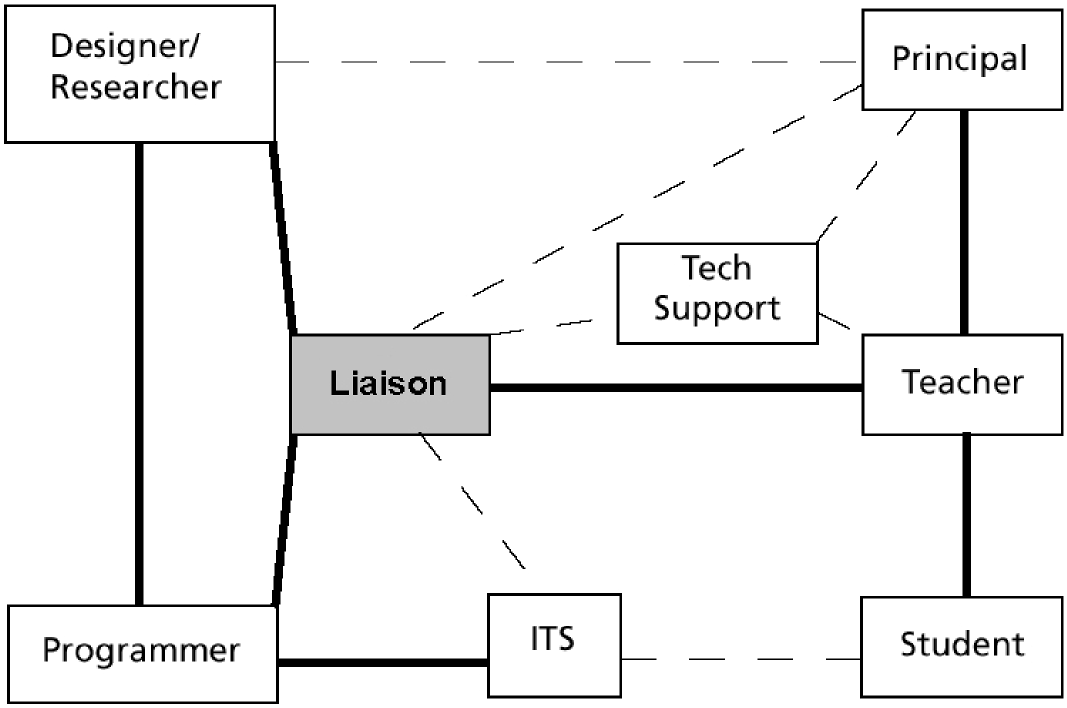

Figure 4: A diagram of the current roles in the PACT Center, based upon our contextual inquiry.

3. The Technical Liaison, as The Liaison

During the PACT Center's relatively long history of deploying prototype intelligent tutoring software to schools (now over two decades), our project has often relied upon a liaison to coordinate our collaboration with teachers and schools. Rose has been an especially effective liaison, though not the only highly effective liaison we have had. Her relationship with our collaborating teachers has been an extremely valuable link between the PACT lab and the schools in recent years. Through her relationship with the teachers, Rose has been a key conduit for essential information between the schools and our lab, helping to keep the relationship between the two organizations smooth and mutually beneficial. Through her close working relationships with both researchers and teachers, she has facilitated negotiations about new studies and assisted in scheduling those studies. The PACT lab has several researchers, at both the graduate student and faculty levels, who each have one or more projects within the broader middle school mathematics tutoring effort. Rose has played a important role in negotiating agreements for new projects: explaining the projects, finding out what constraints the researchers should know about, negotiating, and ferrying official letters of agreement back and forth. As the middle school tutoring project has matured, such negotiations have become an increasingly large part of Rose's job.

Her "main" role as a technical liaison facilitates this in several ways. Perhaps the most important way is that she is able to gain the advantages of proximity to teachers in ways that other members of the PACT lab cannot.

Collaboration between two individuals is greatly increased simply by having the two individuals come into regular contact [12]. Rose naturally encounter teachers frequently, because she is frequently physically present at the schools. When Rose is at a school, there are many opportunities to briefly speak with a teacher between (or during) classes. As Rose explained during our CI, these conversations can often be used to propose ideas, make requests, and learn about concerns. Thus, Rose often serves as an informal conduit for communication and negotiation between our project and the schools. These conversations of opportunity can provide the setting for conducting a considerable amount of important business, in a way that is casual and comfortable for both Rose and the teacher – Rose notes that they can also be a very effective way to communicate with teachers who are not easily reached by phone or email. This sort of informal contact has been identified by organizational researchers as a crucial element in the coordination between teams [10].

By contrast, there are few circumstances when it is normal for other project researchers to be at a school. There is no official reason for PACT lab researchers or programmers to be in the school, except specifically to meet with teachers and/or administrators, or in some cases to observe students working with the software (as in [3]). Both of these types of events must be scheduled. Just showing up, without announcement, to meet with a teacher or principal would be rude and presumptuous behavior for a researcher.

It can be quite difficult to meet with a busy individual such as a teacher or principal without the advantages of proximity. For example, "Greg", a graduate student in our laboratory, spent almost an entire month attempting to schedule a meeting with a principal at one school. By contrast, when Greg was at the school to conduct observations, he was able to meet with the principal without any notice. He did so by sitting outside the principal's office for just over an hour, between classes, until the principal had five minutes to speak with him. Showing up, without an excuse, to sit outside the principal's office for an entire hour would have been impolite, and likely would have negatively affected his request. However, since Greg was "already at the school", the principal's administrative assistant was willing to let the Greg wait outside the principal's office until the principal had five minutes.

Rose's presence in schools also allows information to informally travel in the opposite direction -- from teachers and school personnel to the PACT Center's programmers and researchers. Teachers often do not feel comfortable telling lab researchers that a tutor lesson is difficult for students to understand or has a number of bugs – Rose reports that the teachers feel much more comfortable speaking about these issues to her, because she did not write the software or the lesson.[3] Hence, she is able both to commiserate with the teachers about the problem and to bring the information back to the appropriate person in the PACT lab, in order to fix the problem.

In addition to proximity, Rose's relationship with the teachers is facilitated by the very nature of her technical role. Her technical knowledge and frequent presence in the school are directly helpful to teachers. New tutor lessons frequently have bugs, and depending on their severity, these bugs can be a considerable disruption to class. Rose is often present during the first class a new lesson is used, and she is sometimes able to propose workarounds within minutes of a bug's discovery. This minimizes the cost to teachers of participating in a curriculum which is still under active development; Rose attributes a considerable amount of the current cooperation she receives from teachers to the technical assistance she was able to offer in the middle school tutor project's first year.

On the whole, Rose has closer links to the teachers than any other individual on our project. As evidence of this, her frequent interactions with teachers have led to her becoming friends with several teachers, and socializing with them outside of school. Having an individual such as Rose frequently present in the schools as our project's representative helps us successfully deploy our tutors into schools, and helps us make teachers feel valued as an essential part of our research project.

---

[3] Greg corroborates this, noting that, in his presence, teachers are far more willing to criticize tutor lessons he did not write than tutor lessons he wrote.

4. Working With School Technical Support Staff: Challenges and Strategies

In the model shown in Figure 3 (the common-sense model of the relationships that are essential to deploying an intelligent tutor project), the relationship between the installer and the school technical support staff (the "techs") is central; in the model of actual practice in figure 4, this relationship is much weaker. This difference corresponds to the relative frequency of Rose's interactions with these groups of individuals; as we jointly examined her email, it became clear that she exchanges email with the techs and meets with the techs far less frequently than she emails and meets with teachers. Despite the comparative looseness of her relationship with the techs, Rose has been successful at installing software at schools in a timely fashion. We do not recall a single instance where a study was delayed because of installation delays, in the four years she has worked for our project.

The relative looseness of the relationship between Rose and the techs is explainable in part by the techs' job priorities. The techs do not place particularly strong priority on having the tutor software installed and working properly. They have many responsibilities. Each of the techs we work with are responsible for, at minimum, supporting all of the computers and software used in an entire school - and in some cases, multiple schools. The tutor classes are one small part of their responsibilities. Additionally, since the tutor software is supplied and supported by the PACT Center, there is simultaneously comparatively little reward for the techs if the tutor software is working properly, and a natural and credible scapegoat (the PACT Center's programmers) if it is working poorly.

By contrast, the teachers use the cognitive tutor software regularly. If the software fails to work, it is very disruptive to their classes. Similarly, school principals like the prestige of having experimental (but highly acclaimed) intelligent tutoring software used in their schools, and have an interest in the software's success. Hence, the teachers and principals have strong interest in Rose succeeding in getting the software working on the school machines, and Rose is able to leverage her relationship with teachers and administrators to get assistance from the less accessible techs. For instance, in school district "X", where a teacher has a close working relationship with a tech, Rose cc's that teacher on a considerable amount of her email contact with the tech – knowing that the teacher is participating in the conversation is an incentive for the tech to respond more quickly. In school district "Y", Rose had a problematic situation, where a tech was repeatedly failing to install needed system software by the dates he said he would. Rose was able to obtain the principal's assistance in persuading the tech to install the system software sooner. At district Y, Rose reports that other office support staff (such as the principal's assistant) have also assisted her, suggesting places to look for the techs, and repeatedly paging them for her.

Although Rose's relationship with the techs is not nearly so close as her relationship with the teachers, they still regard her positively. For instance, when the PACT center finished a project with school X, and technical support for the project was transferred to the company that distributed the software, school X's techs asked the company if they would pay Rose to provide them future support on that project. After that request was denied, the techs still continued to ask Rose for technical support for that project when she was at school X to install software for later PACT center projects. Rose's positive relationship with the techs at school X has enabled Rose to obtain administrator-level access to their computers, making installation considerably more convenient.

5. Other Individuals Who Can Serve As A Liaison to Teachers

Rose's role as at a technical liaison at the schools has enabled her to be an effective liaison to teachers as well. It is important to note, however, that individuals in other roles can also help coordinate an ITS project's relationship with the schools. Another role which provides such an opportunity is a teacher-designer. One example of this type of liaison was "Jerry", a teacher-designer who served as a liaison to other teachers a few years before Rose joined our project, as our lab was deploying tutors for high school mathematics. Jerry no longer works with our project, but we were able to obtain information about his past role through discussions with researchers who have been with our project for many years.

Our tutors were deployed to many schools beyond Jerry's, and he had fairly little informal contact with teachers at those schools. Thus, Jerry did not have the proximity-effect benefits that Rose is able to take advantage of. However, one factor that undoubtedly assisted Jerry in establishing relationships with teachers was the high level of similarity he had to the other teachers (cf [8]). As a teacher himself, Jerry was able to "speak the other teachers' language", understanding their educational and logistical concerns more naturally than other researchers in our project. Jerry knew how to explain things in a way that other teachers would understand – although, as one researcher in our project put it, "(Jerry) and I could say the exact same thing, and if he said it, they'd listen." Additionally, when the other teachers called Jerry regarding a problem, his shared understanding with the researchers enabled him to quickly and effectively convey the problem to the other researchers. Finally, he served an essential role in persuading teachers to participate in the deployment and investigation of prototypes of our tutors; because, like them, he was a teacher, he had credibility with the teachers, and was seen as understanding the problems teachers face.

The fact that both Rose and Jerry were both able to serve as very effective liaisons between our project and school personnel suggests that there are several ways for a liaison between an ITS project and a school to enable more effective communication and collaboration between these two groups.

6. Conclusions

Rose is effective at installing and maintaining intelligent tutor software at schools in large part because that is not all she does. She fulfills a much more important role: being a liaison between the PACT center and the schools we works with. Her close relationship with teachers allows her to learn about problems with the software, to transfer vital information between the two organizations, and to arrange new studies on the behalf of PACT lab researchers. Her close relationship with teachers also allows her to sidestep the school techs' lack of interest in supporting software installation, by having teachers and principals take part in encouraging the techs to provide assistance. Her close relationship with teachers builds upon two factors: the proximity her technical role at the schools affords, and the benefit provided to teachers by her ability to provide rapid technical support and workarounds for bugs in early versions of the tutoring software.

The deployment of intelligent tutors into schools takes place in a rich environment, where the efforts of many individuals must be coordinated. Many more relationships than just the relationship between the student and the tutoring software must be considered. Rose uses her role installing and maintaining software at the schools to coordinate the efforts of two organizations with fairly different structures and goals - the PACT lab and the schools - towards the same project: developing and deploying high-quality intelligent tutoring systems into schools, to benefit the students who use them.

Overall, it seems clear that having a liaison between the research laboratory and the schools is quite valuable during the deployment phase of an intelligent tutoring project. Rose and Jerry have each been successful at filling this role. In both cases, theirs success is partly due to their natural advantages at communicating with both the research group and school personnel. Rose's role in technical installation and support gives her natural proximity to both groups of people. Jerry was an effective liaison between the PACT lab and the schools because he had common ground with both groups. Both of these individuals were effective at developing close working relationships with teachers. However it is accomplished, large-scale educational technology projects will benefit from having at least one person on their team who serves as a bridge between the project and its partner schools.

Acknowledgements

We would like to thank Jack Mostow, Laura Dabbish, Shelley Evenson, John Graham, and Kurt vanLehn for helpful suggestions and feedback. This work was funded by an NDSEG (National Defense Science and Engineering Graduate) Fellowship, and by NSF grant 9720359 to "CIRCLE: Center for Interdisciplinary Research in Constructive Learning Environments".

References

[1] Aleven, V., Koedinger, K.R., Popescu, O. (2003) A Tutorial Dialog System to Support Self-explanation: Evaluation and Open Questions. *Proceedings of the Conference on Artificial Intelligence in Education*, 39-46.

[2] Baker R.S., Corbett A.T., Koedinger K.R., Schneider, M.P. (2003) A Formative Evaluation of a Tutor for Scatterplot Generation: Evidence on Difficulty Factors. *Proceedings of the Conference on Artificial Intelligence in Education*, 107-115.

[3] Baker, R.S., Corbett, A.T., Koedinger, K.R., Wagner, A.Z. (2004) Off-Task Behavior in the Cognitive Tutor Classroom: When Students "Game the System". To appear in *Proceedings of ACM CHI'2004 Conference on Human Factors in Computing Systems.*

[4] Beyer, H., Holtzblatt, K. (1998) *Contextual Design: Defining Customer-Centered Systems.* London, UK: Academic Press.

[5] Corbett, A.T., Koedinger, K.R., & Hadley, W. S. (2001). Cognitive Tutors: From the research classroom to all classrooms. In P. Goodman (Ed.), *Technology enhanced learning: Opportunities for change* (pp. 235-263). Mahwah, NJ : Lawrence Erlbaum Associates .

[6] Corbett, A., Wagner, A., Raspat, J. (2003) The Impact of Analysing Example Solutions on Problem Solving in a Pre-Algebra Tutor. *Proceedings of the Conference of Artificial Intelligence in Education,* 133-140.

[7] Greenbaum, J., Kyng, M. (1991) *Design at Work: Cooperative Design of Computer Systems.* Hillsdale, NJ: Lawrence Erlbaum Associates.

[8] Hovland, C. I., Janis, I. L. and Kelley, H. H. (1953) *Communications and persuasion: Psychological studies in opinion change*, New Haven, CT: Yale University Press

[9] Koedinger, K.R. (2002) Toward evidence for instructional design principles: Examples from Cognitive Tutor Math 6. Invited paper in *Proceedings of PME-NA XXXIII (the North American Chapter of the International Group for the Psychology of Mathematics Education).*

[10] Kraut, R.E., Fish, R., Root, R., Chalafonte, B. (1990) Informal communication in organizations: Form, function, and technology. In S. Okamp & S. Spacapan (Eds.), *Human Reactions to technology: Claremont symposium on applied social psychology,* pp. 145-199. Beverly Hills, CA: Sage Publications.

[11] Schofield, J.W. (1995) *Computers and Classroom Culture.* Cambridge, UK: Cambridge University Press.

[12] Segal, M. (1974) Alphabet and Attraction: An Unobtrusive Measure of the Effect of Propinquity in a Field Setting. *Journal of Personality and Social Psychology,* 30 (5), 654-657.

[13] Wenger, E. (1987) *Artificial Intelligence and Intelligent Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge.* Los Altos, CA: Morgan Kaufmann.