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ABSTRACT

This paper reports on a study of the spread of an educational innovation that used computer technology and software called "Geometric Supposers" to integrate inductive reasoning into geometry courses in three high schools. The study documented the efforts of teachers, who had worked with this innovation during the previous year, to support its dissemination to their colleagues. Three case studies documenting the dissemination of the "Supposers" are given. In each study, the school setting, context arrangement, instructional design, and school structure and fit are described. A final section compares the three cases focusing on ways of securing support for the innovation, recruiting new teachers, and providing instruction and implementation assistance. (YP)

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EXTENDING TECHNOLOGICAL INNOVATIONS IN SCHOOLS: THREE CASE STUDIES AND ANALYSIS

Technical Report

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We also wish to thank Daniel Chazan, Magdalene Lampert, Judah Schwartz, and Maxwell West who offered valuable consultation and assistance throughout the project.

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I. INTRODUCTION

This paper reports a study of the spread of an educational innovation that used computer technology and software called *The Geometric Supposers* to integrate inductive reasoning into geometry courses in three secondary schools. The study documented the efforts of teachers, who had worked with this innovation during the previous year, to support its dissemination to their colleagues. Each school's story is presented in a case study that describes the dissemination efforts in relation to the school's structures and values. A final section compares the three cases focusing on ways of securing support for the innovation, recruiting new teachers, and providing instruction and implementation assistance.

1: Background

The *Geometric Supposers* (Schwartz et al., 1985-87) are a series of computer software programs designed to help teachers and students construct knowledge of geometry inductively, developing conjectures and testing them empirically. Through a fairly simple menu, the software allows the user to construct a geometric figure (circle, quadrilateral, or triangle), draw additional elements (e.g. tangent, angle bisector, median), measure entities (e.g. angles, line segments, areas, perimeters), and compute relationships among quantities. Having made a construction, the user can then repeat it on another figure of the same type, either specified by the user or randomly generated by the program. The "repeat" feature of the menu facilitates the testing of conjectures about geometric relationships, enabling the user to see whether visual or numerical patterns hold across cases.

In this paper, the "innovation" is broadly construed to include not only the computer technology and *Supposer* software, but also ways of teaching with this technology that integrated inductive reasoning into geometry courses. This instructional approach included the teachers' posing particular problems to students which they explored with the computer in pairs or independently. Teachers guided students to gather data, make conjectures about the patterns they discerned, and develop arguments about the generalizability of their conjectures. Teachers then led class discussions to help students integrate these inductive reasoning exercises with the deductive process of developing formal proofs. The shift toward guided inquiry, helping students develop and defend their own ideas is a major one for most teachers. It entails fundamental changes not merely in technology, but in curriculum, in the social organization and management of the classroom, in teaching approach, and ultimately in basic beliefs about the nature of knowledge and the roles of teachers and learners.

Ways of using this software to support inquiry learning in secondary level geometry were explored first by Education Development Center where the software was developed, and subsequently by the Educational Technology Center. The Educational Technology Center (ETC) conducts collaborative research on ways of using new technologies to improve teaching for understanding. As part of this effort, during the 1986-87 academic year ETC supported and studied laboratory sites in several high schools. The three schools featured in this study were each located in a school system which had originally been invited to participate in the ETC consortium. The school systems were selected to include a range of urban, suburban, and rural districts. The schools became ETC laboratory sites after their administrators and faculty volunteered to participate in the project. More details about the schools themselves and the participating teachers are presented in each case. In these sites ETC studied what forms of implementation assistance helped school teachers carry out research-based innovations that integrated new technologies and guided inquiry approaches into science and mathematics instruction. [See McDowell, et al., 1987 and Wiske, et al., 1988, for reports on this research.] At the end of that year, geometry teachers in three laboratory sites decided that they not only wanted to continue guided inquiry with the *Supposers* in their own classes, but wished to support the spread of this approach to colleagues within their school.

Researchers at ETC took advantage of this opportunity to learn how technology-enhanced guided inquiry approaches to mathematics instruction can be supported and sustained within schools after most external support for innovation is withdrawn. During the 1987-88 year the three schools retained computer equipment and software originally provided by ETC. The veteran teachers (those who had taught with the *Supposers* the previous year as part of ETC's laboratory sites project) received some support from an advisor who observed their classes every several weeks and consulted with them about teaching issues. [See Wiske & Houde, 1988, and Lampert 1988b for discussions of their teaching experiences.] The teachers also met together with the advisor and ETC researchers every month or two to discuss both their own teaching experiences and their efforts to disseminate the innovation. They worked very independently of ETC, however, in designing the spread of the innovation, in acquiring necessary resources and supports, and in providing instruction and assistance to their colleagues. While ETC continued to play a part in the processes it studied, the innovation spread effort was almost entirely planned and conducted by the teachers themselves.

2: Methods

The process of collecting and analyzing data for this study reflected the combined research backgrounds of the two authors. The first author is an

anthropologist whose previous research utilized symbolic techniques to examine social and cultural patterns. With a theoretical perspective emphasizing the significance of underlying systems of meaning, her approach focused upon the interaction among school values and structural relationships. The second author has conducted case study research in educational settings for many years, recently focusing on the process of integrating technology-enhanced guided inquiry approaches into school curricula and practice. She viewed the study from the perspective of research on the process of school and teacher change.

Throughout the year, the first author made frequent visits (approximately every 1-2 weeks) to each of the schools. The basic methodology involved taking part in events such as *Supposer* instructional sessions, observing classes in which the *Supposer* was used, attending meetings among teachers and/or teachers and researchers, and, always, talking with everyone about how they perceived what was happening. Regular discussions between the two authors served to identify emerging themes, relate them to themes in the literature on educational innovation in schools, and clarify research paths to be pursued during subsequent school visits. As hypotheses were developed about the impact of particular structures on the innovation spread process, they were shared with of the participants as a way of testing their validity and explanatory power.

3: Analysis

(1) Three complete case studies documenting the spread of *Supposer* use in each school are presented. These detailed stories of how events unfolded are relatively unstructured, allowing each reader to focus on those aspects of most interest to him or her, to examine what things lead to what, and to sample a variety of different approaches to the same task. The role of existing school values and structures in what occurred in each place is stressed throughout, as the significance of these differences is often underestimated.

(2) The analysis section that follows the case studies, compares the three schools' experiences in order to highlight significant relationships between school structures and the spread process. What works well in one environment will not necessarily work in another. Attending to the ways that decisions made in one part of the spread process influence what happens in other areas may be more important than recommending specific procedures for all schools. Rather than implicitly comparing each school to an assumed "best procedure," the analysis attempts to explicitly contrast what schools actually could and did do. The point of these comparisons is not to say that one approach worked better than the others, but to map

out the linkages among school values and structures, dissemination designs, and the trades-offs involved in each route.

(3) The issues that surface from the comparison of data drawn from the case studies corresponded, in some cases, to issues which have appeared in the literature on education. A number of those issues are directly addressed in this analysis: who should control what aspects of the dissemination of innovations, the implications of central office mandates or teacher choice in recruiting teacher involvement, the role of instructional design in what is learned and the efficiency of the process, and the relative merits of actively constructing knowledge out of use and adaptation in contrast to telling teachers what they need to know and how to use it.

(4) The concept of "structure" was found to play a key role both in understanding how each school operated and in comparing the processes across schools. As the concept has been used in this paper it differs from a more common use found in educational research, i.e. a behaviorist focus upon the tension between an "official" structure of roles and an "informal" structure of actual social interactions. Here the focus has been on the underlying structure of values and meanings which are recognizable in both the official and the informal systems that have been adopted, in the participants' notions of how events, persons, and procedures are interrelated, in the organization of time and space within these environments, and in reappearing patterns for decision-making and the distribution of power. This concept of structure is important because it provides a link between the model for how to do things in each environment and peoples' model of how things should happen. The pivotal, dual role of structure as both expression and shaper of values is important to recognize in order to increase understanding of actual events and to indicate avenues for ideological change.

II: CASE STUDIES

A: CULVER CLASSIC AND DAY HIGH SCHOOL

1: The School

One image of Culver features two of the most prestigious universities in the country and plush neighborhoods of lovely old homes. Another vision shows Culver as an urban, industrialized community with a population density of 15,252 persons per square mile. Still another image portrays it as the beach upon which wave after wave of immigrants from all over the world have landed for many generations, Culver having been declared "Sanctuary City" a few years ago. None of those versions of Culver is incorrect as all are simultaneously present, like slides overlaid in a projector.

The density of social variation found in Culver is funneled into the school system. Culver schools report that 46% of their students are classified as minority students, the breakdown of the students into "racial" categories indicating: 16 Native American, 2348 Black, 4134 White, 511 Asian, 86 Black/Hispanic, and 801 White/Hispanic. The amount of education received by the parents of those students ranges from a disproportionate number of Ph.Ds, due to the academic elements of the community, to a disproportionate number of residents with very little formal schooling, due to the number of immigrants from societies where education is reserved for elites. Under a state law requiring a school system to offer special instruction for any group of 20 students in the system who speak a native language other than English, Culver schools offer bilingual training in: Portuguese, Spanish, Haitian French, Haitian Creole, Korean, Mandarin Chinese, Cantonese Chinese, Hindi, Gujarati, and Vietnamese.

One high school serves all of Culver, Culver Classic and Day School including within its 2,513 students all of the social variation of the community. Among the students at Culver 46 different primary languages are spoken and 64 different nations are represented. The intense diversity in the economic and educational backgrounds of these students has promoted enormous variations in motivation and skills. Approximately 55% of Culver Classic and Day students go on to college, yet the dropout rate is 9-12%. Teachers describe with pride the cooperative interaction of the students and are themselves willing to respond to a demanding variety of special needs, such as finding a Calculus text book in Korean for a talented student whose English does not match her mathematics ability. The character of Culver Classic and Day High School is, to a large degree, formed by its constant attempts to be responsive to the needs of its varied students. That responsiveness, and the complexity which it generates, can be read in the number and diversity of special programs found at Culver.

There are nine "houses" at Culver Classic and Day, many of which have a specialized function within the high school. The Fundamental School curriculum emphasizes basic reading and mathematics skills and a core foundation in science and humanities. The Culver Technical Vocational Program attempts to balance vocational/technical training with enough college preparatory courses that a student has maximum options upon graduation. The Pilot School stresses the creation of a community of students, parents, and educators focused upon the needs and concerns of the individual students, such as decision making skills, and the quality of relationships. There are four "Main Stream" houses at Culver, Houses A, B, C, and D. The bilingual programs of the high school are all housed within and administrated by House D, most of the bilingual students at Culver and the teachers involved in teaching bilingual classes being members of House D. The Achievement School

offers seventh and eighth grade courses for students too old to be placed in a middle school. The Enterprise Co-op is an alternative career-oriented program for dropouts and potential dropouts which involves student run businesses.

The sprawling complex of Culver displays the social organization and the history of the school in spatial terms. The Fundamental School is located on the fourth floor of the old Culver Classic building, the Pilot School on the the fifth floor of that building, and House D is found in the new Arts building, joined to the Classic building by walkways. Teachers at Culver frequently mention the merger of Culver Classic and Culver Day, an event which occurred nine years ago. The building which housed Culver Classic was torn down at that time, Culver Day was renovated, and the Arts building was constructed. The physical structure of Culver, two separate four and five storey buildings of different styles and ages, connected only by walkways on the second and third floors, creates problems for the teachers and students simply because travel from one area to another is so difficult and time consuming. Houses have a spatial location which can isolate them and make interaction with other units difficult. For some of the houses, such as the Pilot School, this has made it easier for them to develop their own "character" within their own turf. But it lessens contact between teachers involved in the different programs and increases the sense of separation among sub-units of Culver. Teachers in one house often have difficulty explaining what the other programs are about, students are hesitant to enter "foreign" territory, and the sense of Culver as a complex world beyond the comprehension of any of its members is heightened.

The merger of the two high schools has become a continuing event, brought into the present not only by the oddly-joined dissimilar buildings and the teachers' memories, but by an unresolved social order which owes some of its instability to the merger. The effects of a series of new administrators (there have been 5 superintendents in the last 17 years), each proposing new plans, have combined with the on-going efforts of the school to respond to the constantly changing community, producing a jumble of organizational concepts, each grafted onto the existing structure wherever a fertile spot could be found. The complexity of Culver stems not only from size and/or multiple subdivisions; it is a complexity of historical addition, formed by an evolutionary process rather than developed according to a consistent structural plan. The social organization of Culver is a gerry-rigged system, built of dissimilar parts and hinged in unexpected places.

Jurisdictions, responsibilities, and procedures vary among the sub-units within Culver as does the nature of their interelationships. The Vocational Program, for example, reports directly to the superintendent's office, not the high school administration. Some houses require absence slips from their students, while others

do not. Many teachers believe that members of the faculty are treated differently in different houses, departments, and programs. Teachers at Culver consistently talk about the "political" nature of the place; they are often hesitant to express an opinion and often finish a discussion with a joke about not using their name. Both teachers and administrators say things such as "the walls have ears" or "that's not worth my job." The confusing nature of the system at Culver provides an environment which fosters insecurity, suspicion, and political maneuvering. When the structural relationships in an organization are not clear, when jurisdictions are over-lapping, and when the pathways for obtaining things are not apparent, then personal networks and political alliances tend to develop as the easiest way to accomplish things. And, as personal and political networks operate behind the scenes, the mechanics for the structure become even more mysterious and, thus, more governed by personal and political ties. The ambiguity of the social organization creates dark pockets in which mistrust among teachers and administrators can grow.

Both the instability of the community which Culver serves, with its constant demands to accommodate new and yet more varied populations, and the tangled structure of the school's social organization tend to set changes in motion. Changes are often far-reaching; one teacher commented that "sometimes it's almost like getting a new job." Keeping one's balance amid these shifting sands can be such a demanding task that the infrequency of complaints about "stagnation" from the teachers at Culver is easily understood.

At Culver course assignments and curriculum become the stable elements in the system, the solid core which the teachers can predict and over which they can exercise control. Course assignment procedures vary among departments and programs, but there is generally an attempt to assure teachers of having at least one course they would like to teach. Once a particular configuration of courses has been arrived at for a particular teacher, it tends to change little from year to year. Teachers polish and hone the courses they teach year after year, tending to resist changes in their curriculum that would disrupt these refined course schemes. There are no department wide exams for subjects at Culver and teachers, thus, are free to develop their course according to their own priorities. The degree of constraint which they feel varies with the subject matter, the level of students, whether the students will be taking standarized achievement exams, and/or whether the course is a prerequisite for another subject. The teachers' relative autonomy over their curriculum at Culver provides both a source for professional pride and a stability within the shifting complexity of the school.

Recruiting Culver High School teachers to participate in ETC activities, including the laboratory site project, was often difficult. The original reason given

for the reluctance of the teachers to participate was the "bad history" of university-based projects at Culver. Stories of events, such as teachers who had lost their positions in the high school after taking time off to work on such projects, had fed teacher distrust. Teachers perceived their relationship to university-based projects as marked by unrecognized and/or unrewarded effort, while the university personnel benefitted by securing the data they needed for their research. Culver administrators could not afford to be perceived by teachers as supporting projects which the teachers viewed as exploitive. Teachers at Culver often saw professionalism in terms of a collection of contractual rights and privileges which defined and protected their control over their environment. They negotiated with external authority, such as ETC, in the same manner that they bargained with their own administration. The uneven, complex, and entangled structure at Culver had promoted an overall uncertainty about how things happen within the school and a lack of trust. It is probably significant that the only Culver mathematics teacher who did volunteer to try the *Supposer* was a relatively new and junior teacher. Greg Sander had taught in Culver for six years within the experimental Pilot School which had originally been designed in collaboration with Harvard University.

2: Arranging the Context for Dissemination

Greg began organizing the process of instructing his colleagues in *Supposer* use toward the end of the first year of the laboratory site project. He offered a demonstration of the *Supposer* in a mathematics department meeting and, following the model of the research project in which he had been involved, asked for volunteers interested in committing themselves to using the *Supposer* throughout the next year. While the schedules for the upcoming year were still being arranged, Greg told the chairman of the math department which teachers intended to use the *Supposer* and requested the scheduling arrangements he felt would be necessary. These three teachers taught in three different houses — the Fundamentals School and two different houses of the Main Campus . Greg worked with the administrators of the houses who agreed to arrange classes in such a manner that the teachers taught geometry at different times, making the computer lab always available for their use. In addition, Greg had his free periods, as he was teaching a reduced course load, scheduled to coincide with the times when the three new *Supposer* users would be teaching geometry. In spite of the fact that the four teachers using the *Supposer* were members of four separately administered programs, the complexities of the schedules were eventually settled after the head of the Fundamentals School rescheduled one entire class of geometry students in the fall. The three new *Supposer* using teachers were supplied by the school with computers to use over the summer and Greg gave

them each the *Supposer* software and a full set of the *Supposer* problems he had received from ETC.

Greg also managed to arrange a way of offering workshops for these teachers by working within a new staff development program. Culver administration had arranged a series of early release days and additional after-school meetings in response to teachers' requests for non-teaching time to explore innovations in their field. As part of this professional development program, the teachers were required to attend one of a series of courses, offered on the early release days and taught by Culver teachers and administrators, and, in addition, to spend a series of one hour periods in after-school "interest" meetings. Greg tapped into these new programs, offering instruction in *Supposer* use as one of the courses and arranging for four monthly meetings among himself and the three new *Supposer* users to be counted as after-school "interest" meetings.

When the new *Supposer* teachers requested payment for their participation in this project (knowing that ETC had paid teachers who participated in the their laboratory site research the previous year), Greg managed to find funds. He asked ETC to give the teachers a small stipend and, following advice from the mathematics department chair, applied for a grant that supplied additional payments for the three new *Supposer* teachers. Before the year of *Supposer* dissemination even began, Greg had put a great deal of effort into setting in place a formalized structure for *Supposer* instruction and securing considerable support for the new *Supposer* users in the form of stipends, course scheduling, and time for both instruction and discussion. His approach was modeled on the types of assistance ETC had offered during the initial year of research, but was adapted to the structure and current programs of Culver.

3: Instructional Design

Eleven teachers enrolled in Greg's course on *Supposer* use, including the three teachers already committed to using the *Supposer* in their classes. Only six of the teachers attending the course were currently teaching geometry, representing approximately half of the thirteen faculty members teaching geometry at Culver. Most of the other five teachers in the course did not expect to teach geometry in the near future, but found the *Supposer* course the most interesting of their options, as they were required to sign up for some course. Mathematics courses at Culver are tracked by student ability in all but the Pilot School; the members of the class included one teacher of "honors", two of "standard" geometry, and three who taught "basic" geometry. The after school "interest" meetings, which Greg had expected would include only the three new *Supposer* users and himself, were attended by two

additional mathematics teachers. Both joined the *Supposer* meetings because they had not found any other meetings which really interested them and, again, attendance at some meeting was required. Only one of those two extra teachers was enrolled in Greg's *Supposer* course. Teacher accountability at Culver is most often measured by teacher time expended, the easiest measure of teacher effort. In keeping with this pattern, the school administration asked Greg to take attendance in both the *Supposer* course and the after school *Supposer* meetings.

Greg taught his own geometry classes with a counter-puncher style, waiting for the students to offer ideas and then interpreting those ideas to move toward the lesson he wanted to teach. But, in teaching the course on *Supposer* use to his colleagues, he felt overwhelmed by the variation in their knowledge. They varied from a guidance counselor, who had not taught any math for many years, to a very senior mathematics teacher, who taught only honors and advanced placement mathematics courses. The participants included three teachers who had committed themselves to teaching with the *Supposer* along with others who would have no opportunity to do so. He opted for a more directed format as the only safe approach to coping with this variation. During the first of the four three-hour sessions the teachers worked in teams on exercises Greg had prepared, using wooden cubes as well as the *Supposer*; Greg then led a discussion on inductive approaches to geometry. Following that he led the teachers through the menu for the *Supposer* software in unison. Concerned that the most mathematically sophisticated teachers in the group had not seen the inductive exercises in this session as challenging, Greg asked one of the the ETC researchers to present a very sophisticated *Supposer* problem during the next session. On the day before that session, the three-hour period which had been designated for the course was cut to a two-hour period, the administration's response to Culver teachers' outrage at the massive amount of time they had suddenly found themselves committing to such courses, "interest" meetings, and a collection of other staff development projects. Following the ETC researcher's presentation during the second session, Greg compressed his agenda into a lecture on *Supposer* 's potential for teaching and learning, allowing the teachers no opportunity to experiment with the *Supposer*. The third session followed more closely Greg's accustomed classroom use of the *Supposer*. He distributed a set of *Supposer* problems for the teachers to work on, and then led a discussion of the experiences encountered in solving those problems. The final session of the course, which had been expanded to three hours once again, focused upon three variations of a *Supposer* problem that Greg had prepared, adaptations which he felt reflected the types of changes necessary to match the student ability levels of the three-track system at Culver.

During the "interest" meetings after school, Greg waited for the teachers to bring up their problems, compare their experiences, and discuss the process of teaching

with the *Supposer*. Instead, the teachers asked Greg for problems to use for specific topics and continued to discuss the *Supposer* only in very general terms. The teachers tended to use Greg, the *Supposer* course, and the after school meetings as resources for information about the *Supposer*, not as sounding boards for discussion and feedback about their own experiences with the innovation. The presence of "extra" teachers, members of the Culver mathematics faculty who were either not enrolled in the *Supposer* course or not using the *Supposer* in their classrooms, also forced these meetings to be kept at a generalized level.

The multiple houses and tracking systems of Culver have interacted with the lack of course rotation and curriculum accountability in the school to produce teachers who have become highly specialized in teaching very specific courses. Culver teachers, therefore, tended to be interested in the *Supposer* to the degree that it could be incorporated into their well-honed curricula and to use it within the patterns of teaching which they had already developed. One new *Supposer* teacher remarked that her use of the tool and evaluation of it had to be understood as "coming from the perspective of having taught an honors class for many years." All of the new *Supposer* teachers set off to use the tool according to their own , already set, notions of what they were doing, exploring the innovation's implications only within that narrowed perspective. These teachers' interests in the innovation were shaped by how they could use it in their courses, yet the course on *Supposer* instruction mostly offered a generalized introduction to the tool, as it was taught within the logistics and politics of a pan-school staff development program. The administration's perception of innovation spread as the distribution of information, which the teachers were held responsible for being there to receive, failed to mesh with the teachers' perception of needing time for adaptation and specialized discussion in order to use the *Supposer*.

Greg's own courses, taught within the untracked Pilot School, had been relatively unaffected by issues of adaptation of *Supposer* use to student ability during his first year of work with the *Supposer*. The group meetings organized by ETC among the veteran teachers had been structured to focus more on ways of promoting inquiry learning than on alternative ways of teaching with the *Supposer* to suit teachers' different styles and perceived student needs. As Greg worked with his colleagues on *Supposer* use, however, he became so aware of these alternatives that he made them the topic for a research paper he wrote as a graduate student. He challenged what he saw as the ETC researchers' "hidden agenda" regarding appropriate *Supposer* use, which he felt ignored adaptations that were necessary for lower ability geometry students. Greg's interest grew out of his contact with the new *Supposer* users, whose perceptions were tightly focused by their long experience with particular types of students. Because he had not anticipated the importance of adapting the innovation for students of different ability levels, Greg did not address

this topic until the last session of the *Supposer* course which occurred in March. Some of the teachers attempting to use the tool in their classrooms had by then come to the conclusion that the course was too general and, therefore, not practical.

Because all of the teachers using the *Supposer* were in different houses, there was little contact among them outside the four after school "interest" meetings, which had been grouped near the beginning of the year. Sometimes weeks elapsed before Greg learned whether the materials he had worked on with teachers had even been used. None of the new *Supposer* users sought Greg out after using the *Supposer* with students to discuss with him how things had gone and none asked for feedback about how he or she was using the innovation. During most of the year the teachers did not invite Greg to come to their classes and observe their use of the *Supposer* and he felt that he did not have the authority to suggest such visits. Lacking evidence of how the teachers were actually using the innovation, he felt unable to offer feedback. Eventually he was able to observe how the teachers conducted their *Supposer* labs, but not how they related that data gathering experience back to the concepts of geometry in the classes following *Supposer* lab periods. Greg often interpreted his difficulties in getting into other teachers classrooms and promoting meaningful discussion about *Supposer* use in terms of what he saw as status differences between himself and some of the other teachers. But status differences may have had less to do with Greg's difficulties than the structure of Culver, which promotes teachers' need for control over their own classrooms and creates an uncertainty among teachers about the nature of their interrelationships.

Greg was reasonably content with the course he had taught on *Supposer* use, although he felt, in retrospect, that it may have been too tightly controlled. He believed that the amount of time he had spent presenting had been necessary in order to pass on enough of the important information he had received from ETC during the previous year. Greg was also concerned that the teachers needed to understand what he called "the higher order pedagogy it (the *Supposer*) addressed." He wanted to point out in advance the shifts to a guided inquiry style of teaching and the more inductive approach to geometry which use of the *Supposer* could generate. Greg felt frustrated, however, about the nature of the discussions he had had with the three new *Supposer* users. As in the "interest" meetings, the teachers had tended to approach Greg as a resource, asking for help in supplying and explaining *Supposer* problems for them to use in their courses rather than discussing their experiences with the innovation.

Among the eleven teachers who attended the *Supposer* course, only the three who had committed themselves at the beginning of the year to using the *Supposer* actually used the innovation in their classrooms. One teacher within Greg's house

did, however, begin to use the *Supposer* in his geometry course, although he had not signed up for the formal *Supposer* course. One of the new *Supposer* users hoped to secure administrative assistance for her plan to introduce the *Supposer* to her colleagues within her house during the next year, as several of those teachers had mentioned that they would feel more secure working with her within the house structure. However, she feared that the logistics of arranging course assignments, course schedules, free period schedules, and computer lab schedules without the support offered through the school-wide staff development program would be overwhelming due to the complexities of jurisdictions in the school.

Because Greg had spent so much time and energy on the *Supposer* course, and because he had enjoyed the opportunity to work with other teachers, he began, in the spring, organizing the same course for the next year. He surveyed all of the mathematics teachers at Culver who had not already elected the *Supposer* course, contacting them when possible to discuss the course. Just when he felt that a sufficient number of teachers probably would select the course for it to be offered, the Culver superintendent announced his resignation. This called into question whether the elaborate staff development program that had so dominated the present year would still exist during the next year and, if it did, whether its form would still include a selection of courses taught by teachers during a series of early release days.

4: Structure and Fit

In terms of the types of support ETC offered to lab site teachers during the first year of this project, Culver was extremely supportive of innovation spread during the second year. But the attempt to disseminate *Supposer* use at Culver followed the lines of the ambitious school-wide staff development program. The fractured, distrustful relationships which the structure of Culver promoted provided poor soil for flexible, supportive sharing among colleagues. Within the various houses in Culver, where teachers' relationships were more trusting, teachers exercised more control over their activities, and interactions were more frequent, the spread of *Supposer* use occurred more easily. The formal dissemination of *Supposer* use was organized without consideration of the segmented structure of Culver, however, and cut across the existing networks of trust and communication rather than taking advantage of those structures.

The formal staff development program was also ill-suited in several respects to the requirements of this particular innovation. However generous the Culver school administration was in its support, its control over instructional arrangements and teacher participation provided a poor model within which to understand the pedagogical shift to more student control that was promoted by *Supposer* use. Also,

due to the range in interest and mathematics experience of the teachers selecting the *Supposer* course, Greg felt compelled to emphasize the "guided" aspect of the guided inquiry methodology. Because many of the teachers enrolled in the course did not currently teach geometry, Greg could not design his instruction to interact with the teachers actual experiences in using the tool. The formal staff development program constrained his teaching teachers in a way that fully modeled the way he hoped they would teach students.

B: WILLIS HIGH SCHOOL

1: The School

The town of Willis is located approximately 75 miles west of the Boston area, too far for commuting to the urban hub and yet not really part of rural Western Mass. It used to be a thriving mill town, with bustling textile mills and shoe factories surrounded by productive farm land, but the bottom dropped out of the mills in the late 1950s and '60s. Many people left; others found jobs in the insurance businesses in the nearest city or the factories in nearby towns. Gradually Willis became a "bedroom community" for these larger towns and now, because the prices of land are lower in Willis than in many other areas, new residents are beginning to move into the community.

The 1980 census showed that only 56% of the adult residents of Willis had completed high school and only 8.7% had finished college. In the eight years since that census was taken both of those figures have probably risen, but expectations about education have probably increased far more dramatically. Many of the new members of the community no longer view high school graduation as the goal, being more concerned with the preparation which high school will give their children for college. Older residents, who were themselves content to remain in the community of their parents, believe that their children will leave Willis and want them to gain the skills necessary for moving into a larger and more complex world.

Teachers and administrators at Willis comment on the enthusiasm generated by having someone from "out there" pay attention, "out there" being defined as "non-Willis." The superintendent of Willis schools says that "the stranger with the briefcase" is almost always viewed positively by both faculty and students who want their community to be recognized. One teacher, who returned to Willis after a long absence, commented that anyone who had lived and worked in the world beyond Willis was considered an expert. A number of the teachers described the process of becoming involved in the ETC laboratory site project as a prize to be won, one saying " this made us think, if we get accepted into the project, it's really going to be

great. We ended up getting accepted and we were very enthusiastic about being in it."

In spite of all the projection, anticipation, and interest in change, life in Willis High School has not changed dramatically over the years. "Even the cafeteria help has been here for 10 -20 years," one teacher remarked. Most of the 35 faculty members have been at the high school for over 15 years and only four new teachers have been hired in the last eight years. A teacher who graduated from Willis High School 40 years ago said there seemed to have been little change in the attitudes of the students, interest in sports and proms still being much greater than in colleges and careers. He did, however, note one difference very much in keeping with the growing concern with education in Willis: his freshman class of 40 years ago was approximately the same size as the current freshman class, between 100 and 150 students; but only 55 of his classmates graduated, compared to 122 graduates in 1985. Consequently, while the population of the town has remained around 8,000, the total number of students in the high school has grown from approximately 250 students 40 years ago to 453 students in 1985. Although more students stay in school until they graduate, teachers report that at least 10 -15% of the students have no desire to stay and some students admit that they remain only because their parents require it in order to receive welfare. Of the 122 students who graduated from Willis High School in 1985, 31 went on to 2-year colleges and 30 to 4-year colleges, one half of the graduating seniors continuing their education beyond high school.

The intimacy of students and staff in the Willis school system is due not only to its small population, but also to the close proximity of everyone and everything. The superintendent's office is located in the elementary school just across a parking lot from the high school. The high school is a single-storey building of traditional, 1960s construction: straight corridors lined with lockers and classrooms. The teachers' lunch room also contains their mailboxes and copying machine. It seems impossible to be in Willis High School for more than an hour and not run into whomever one wants to meet. Students passing out of a class inform the students coming in what was covered; teachers compare notes on how a topic went as they pass in the hall. There are no security guards in the halls nor even any teachers with "hall duty," as all that is going on can readily be observed. Everyone in Willis High School is available on an easy, informal basis, but is also open to constant scrutiny. A secretary in the high school office commented that she had "moved to Willis because of the schools. I wanted a place where my children weren't just numbers and where I would know who their friends were." She not only knows what her own children are doing, who they are associating with, and what their world is like, but also knows the same thing about every other student in the school. Conversations

over lunch move easily from teachers' personal lives to discussions of students as no member of the school community is unknown to everyone present.

Visitors to Willis High School, "outsiders with briefcases," are almost always treated to lunch in the cafeteria. This is only partly because they are outsiders, perceived as bringing desireable expertise of the urban world into the system. Each spring a special meal is prepared in the Willis High School cafeteria, table cloths are placed on the lunch room tables, and the teachers sit down to eat with their students, "family style." A meal is the traditional American welcome extended by any family to a visitor. The unmitigated scrutiny of each other's behavior, the gossip, and the constant contact among students, teachers, and administrators are all acceptable aspects of life at Willis High School because they occur within a community which defines itself as a "family." The sense that one's children will be looked after and cared for in such a school, not be "just numbers," grows from this conception of the school as a family unit. Maternalistic concern about the well-being of students and colleagues and paternalistic statements such as "then I went to all my science people" or "he talked to his girls" are woven into the fiber of interactions at Willis High School.

The values of the school, like family values, are generalized, not narrowly focused upon academic issues and intellectual growth. The values of Willis High School reflect the standards of a community where the byword is, according to one teacher, "Don't aim too high." While Willis schools have a very good program for students with special needs, they offer almost nothing for talented or gifted students. There is no tracking of students other than in English courses. What is stressed is good behavior. "Do what the teacher tells you," and "Don't get into trouble," are the messages received at home by most students. Nevertheless, parents, teachers, and administrators all share a desire for Willis High School students to acquire the skills they will need in the world beyond Willis. One skill which the school personnel have recently decided will benefit their students is a familiarity with computers.

2: Arranging the Context for Dissemination

The logistics of implementation during the first year of lab site research, such as setting up the computer lab and arranging teacher schedules, were so much easier at Willis than at the other schools that the Willis liaison for the project remarked "As I have listened to my colleagues talk about the problems that they have had, I have said to myself I should give back my stipend because I didn't have those problems." As the liaison described how each step of the implementation process had been dealt with at Willis, he said repeatedly, "I went to the principal and ...." Many decisions

at Willis are made in a top-down manner. Combined with the easy communication, made possible by the school's size, such a pattern can be extremely efficient.

School attitudes about the value of contact with experts outside the community and administrative eagerness to incorporate the use of computers into the school oiled the way for the ETC laboratory site project. The hierarchical structure of the school made the early implementation phases run smoothly in part because ETC's role, due to the status associated with university affiliation, was simply inserted as a top rung in the hierarchy. The various forms of assistance which ETC recommended were all carried out during the initial year of research. The administration and faculty were exceptionally eager to participate in this research project, which brought both computers and educational technology experts into the school. Willis administrators emphasized these concrete aspects of the project, viewing the *Supposer* primarily as a technological innovation rather than a change in the content or process of geometry teaching.

Planning for the spread of *Supposer* use began during the conclusion of the first year of research at Willis also, but the veteran *Supposer* user there, Pamela, had a different role from's at Culver. Both the superintendent and principal at Willis were extremely enthusiastic about the research project and had decided that the *Supposer* would be used in all geometry classes in the school. Pamela's colleague who had used the *Supposer* with her in the lab sites project, left at the end of the year, which meant that a new mathematics teacher must learn to use the *Supposer*. Pamela had little say in who the new mathematics teacher would be; a teacher was hired with the coaching skills that the school needed, but no experience with either computers or teaching geometry. Of the possible people to become the new *Supposer* user, the present programming teacher was selected, in spite of the facts that she had never taught geometry and that she was leaving on a sabbatical for the second half of the year. As it was the computer skills aspect of the project which had been most focused upon at Willis, her computer knowledge, plus the facts that she had already been involved with another ETC research project and that she was considered an exceptionally able teacher, outweighed these drawbacks. She was interested in learning to use the *Supposer* and agreed to take on the project although both she and Pamela were concerned about what would happen when she left during the second semester.

The spread of *Supposer* use at Willis had few formalized aspects. No arrangements were made for time during which Pamela could instruct the new *Supposer* user, discuss with her what they were attempting to do, or resolve any problems which might develop. No concessions were made in the scheduling of classes so that the two teachers could have the same free period or a free period when

the other was teaching geometry. The principal, in consultation with the liaison and participating teachers, had made such arrangements during the preceding year. Pamela had expected similar support to be supplied as she attempted to instruct a colleague in *Supposer* use, but did not feel able to ask for it. Once the computer lab was in place and functioning, because the administrators perceived the project as primarily about computer skills, they thought little additional support was necessary. Neither Pamela nor the new *Supposer* teacher questioned the scheduling of their classes or the lack of time for instruction or discussion.

3: Instructional Design

Contact for instruction in *Supposer* use occurred in the same informal face-to-face manner that most contact happened at Willis: the two teachers met in the classroom which they shared, before school while Pamela was supervising a computer lab, and in the faculty lunch-copy machine-mail room. The time they spent together was always in an environment where other teachers or students placed demands upon their attention. Pamela left her copies of the *Supposer* problems she had received during the first year of ETC research in the desk which she shared with the new *Supposer* teacher, so that the latter could examine them. But it was difficult for the new *Supposer* user to find time during the day to look over the materials and no arrangements were made to copy all the problems for her. With ETC no longer supplying sets of *Supposer* problems for each teacher, even making copies of the previous year's materials became difficult.

Pamela decided which of the *Supposer* problems were to be used, where in the total structure of the geometry course they would be used, and how the geometry course would be organized. To convey these ideas to her colleague, Pamela gave the new *Supposer* user a duplicate copy of the *Supposer* problems that she planned to use in her classes and, if there was time, discussed those problems with her. Generally they were able to meet in the morning, before either of them had any classes, if there had not been an earlier opportunity. Pamela expected the new *Supposer* teacher to cover the same material in her geometry class that Pamela was covering on the same day, but the new *Supposer* user consistently fell behind. The period during which her geometry class met was, because of the lunch schedule, somewhat shorter than the other periods in the day. Pamela was able to leave a study hall she supervised to come to the new *Supposer* teacher's class and always did so when it was a *Supposer* lab. She did not, however, attend the classes in which the new *Supposer* user related what the students had done in lab back to geometry concepts, as she believed that her help was most needed in handling the lab format and her perception of the innovation also tended to emphasize its computer aspects.

The new *Supposer* teacher expressed some frustration about not having a total set of *Supposer* materials to examine. She felt that she had little sense of how the *Supposer* problems could fit in with the geometry concepts taught in the regular course, or even what the overall structure of the geometry course was going to be. She had never taught geometry before and was uncertain about why the order of topics was as it was. In addition, because she taught programming and advised Pamela about computer-related matters, Pamela assumed that she needed little help with this computer-based innovation.

As the semester proceeded, both Pamela and the new *Supposer* user became increasingly concerned about who the replacement teacher would be. Pamela felt that she might be able to come into the new teachers' geometry class and insert the "computer lessons" if the new teacher proved totally unwilling or unable to handle the *Supposer*. Neither teacher protested the policy decisions which had mandated *Supposer* use but had not directed hiring considerations along lines which supported use of the innovation. The only applicant for the job was a student, without teaching experience, who had completed her course work and hoped to use her job at Willis to fulfill her student teaching requirements. She had seen a demonstration of the *Supposer* in a seminar and appeared to be interested in exploring its possibilities. Pamela acknowledged the increased responsibility such an inexperienced teacher would place upon her, but accepted such demands upon her time and energy as part of her job. Her tendency not to differentiate her roles as teacher, department chair, mother of students, and community member provided a flexible net within which she absorbed such extra demands.

Pamela often made changes in the ETC-supplied *Supposer* problems before using them in class, but expected each of the two new *Supposer* teachers to use the same version of the problems as she did. The more experienced teacher, using the *Supposer* during the first semester, felt a need to adapt the *Supposer* lessons for her own classes, but believing that her understanding of geometry was still inadequate, postponed these adaptations until the next year. The new, inexperienced teacher was so overwhelmed by the variety of new experiences that she was delighted to have the *Supposer* lessons prepared for her. Because there was no ability tracking among geometry students at Willis, teachers did not feel compelled to adapt the *Supposer* materials to different classes of students.

Pamela and both of the new *Supposer* users expressed great enthusiasm for the tool and all expected to continue using it during the next year. The manner in which it was used, however, was shaped by the form of instruction which Pamela provided. Because teachers had no time for discussion, because the lack of tracking in Willis' geometry course had not forced adaptation of the innovation for different

groups of students, and because both of the new *Supposer* teachers had never taught geometry before, they tended simply to accept Pamela's *Supposer* lessons as special projects to be injected into their courses. They viewed the *Supposer*-based innovation as a technique to be inserted into the existing geometry curriculum in an additive manner, the major changes being seen as those created by the lab classroom format and student enthusiasm for working on computers.

4: Structure and Fit

The spread of *Supposer* use followed the hierarchical structure of Willis, a phenomenon whose significance is obscured by the fact that Willis' structure is typical of the model generally assumed to exist in schools. The design and on-going supervision of Willis' involvement with ETC was managed by the school superintendent. The principal dictated that the *Supposer* would be used in all geometry classes; the department chair decided who would teach geometry. The experienced *Supposer* teacher determined what materials the new *Supposer* teacher would use, when what geometry topics would be addressed, and how students would be evaluated. The top-down system of authority at Willis mirrors the community's message to its students, "do what the teacher tells you." It is supported by the paternalistic and maternalistic values of the school system and the sense of "family," which discourages objection as a disruption to the overall harmony. While such a hierarchical scheme could be extremely alienating in a large school, the intimate, face-to-face pathways of that structure in a small school, such as Willis, make it function with relatively little tension. But, because decision making and information exchange travel primarily in only one direction within such a structure, the teachers at Willis did not communicate and secure they type of support that they needed.

Willis's system of hierarachical authority tended to undermine rather than reinforce the pedagogical changes which the *Supposer* was designed to promote. The problem was not that control "from above" was heavy-handed or non-supportive; it was more that the assumptions about who should initiate action and exercise authority were deeply ingrained. Willis students, who heard "do what the teacher tells you at home," had difficulty assuming the active role which a guided inquiry approach required of them. The Willis teachers had difficulty asking for the support they needed from administrators and the new *Supposer* users had difficulty modifying the prepared *Supposer* lessons which Pamela supplied. The style of interacting which characterized the social system of Willis did not match the shared authority and responsibility pattern which the *Supposer*-based innovation required.

C: NORVILLE CENTRAL HIGH SCHOOL

1: The School

Norville is a comfortable suburban community, with a high per capita income and essentially no unemployment. Almost half of its residents over 25 year of age have completed four years of college, 96% are white, and only 11.5% were born outside the US. There is great value placed on education in Norville, a value both produced by and reflected in the high percentage of college graduates found in the adult population of the community. Part of the significance given to education can be traced to the history of Norville and the western suburbs of Boston. When those suburbs were first developing, many excluded Jews. Norville was an exception and, therefore, attracted a Jewish population who valued education highly. Enthusiastic support for its schools has always been a characteristic of Norville.

Another feature of the community which has directly affected Norville schools is the sharp increase in property values in the Norville area during recent years. This increase has resulted in fewer young families with children being able to move into the community and a decline in the population of Norville. While a decrease in births has reduced school enrollments nationwide for many years, Norville schools have experienced an exceptionally intense decline in student population. Frequent faculty cutbacks and an almost total absence of new teachers coming into the school deeply affect the attitudes of Norville Central's faculty. Teachers at Norville Central spend a lot of time discussing and working on ways to deal with the stagnation they believe this situation promotes, the most obvious outcome of their attempts at self rejuvenation being 10 PhDs and 160 MAs among a faculty of 205. The lack of new teachers and the rewards offered for early retirement at Norville Central have also created a faculty in a narrow age band, adults who came of age in the late 1960s and, thus, tend to reflect the values of that era.

Norville Central is the larger of two high schools serving its community; it had an enrollment of 2197 students in 1986-87. Approximately 76% of the graduating class of 1983 went on to further schooling, 58% to 4-year colleges. Those students in the 1983 class who took SATs averaged 37 points above the national average on the mathematical section and 25 points above on the verbal portion. The most immediately apparent feature of Norville Central is simply its size, a giant sprawling building constructed in 1973 to accommodate over 2500 students. How Norville Central is physically structured not only shapes what happens within its confines, but reflects both early 1970s values, literally built into it, and the present day values of those who now occupy the high school.

"Main Street" was designed as an open area in which the students and faculty of Norville Central could gather and visit, on the model of a small town's main street.

It physically expresses an "open campus" policy, according to which students and faculty, when not specifically assigned to a class, are free to wander where they wish, an idealistic late 1960s/early 1970s concept which was locked into the building's structure. There is an on-going debate about Main Street at Norville, fueled by variations in the degree to which particular faculty and administrators still espouse the concept. For the students, a totally open campus has not existed since 1976, as the rules about who could be on Main Street when fluctuated over the years while the debate proceeded.

Control is the issue lying at the heart of the Main Street debate and the form of that debate at Norville Central indicates much about the organization of control in the school. In April of 1987 a full-faculty meeting was called to discuss the issues of control and Main Street. Randomly assigned groups broke up to explore aspects of the question, as each person carefully presented his or her position honed by years of thought and debate. Teachers listened to each other, granted the soundness of the points each made, and no conclusion was reached. No administrative authority interfered with the process, declaring what should and would be done. All of the faculty treasured their involvement in constructing school policy, but no consensus was reached and, therefore, nothing was changed.

Most people accustomed to dealing with schools feel disoriented as they enter Norville Central. Part of their confusion is created by numerous corridors winding off Main Street at odd angles (a Norville teacher commented "straight lines are about control") and by the absence of a prominent Principal's Office. In most schools this control center is located front and center, but at Norville Central it is found on the third floor near the rear. Again a concept has been cast in concrete at Norville Central, the role which administration should play in the school being clearly indicated by this placement. The principal of Norville Central for 20 years was in full agreement with this scheme of power arrangements, a man who prided himself on being able to wander the halls of Norville Central without being recognized. He believed in a decentralized system in which teachers played an active role in shaping their school and he was principal for enough years to firmly root those concepts in the organization of the school.

Many teachers at Norville Central are given an office, if they do not have a classroom in which to hang their plants and install file cabinets. Tiny and airless as these rooms may be, their symbolic importance is great as they acknowledge the professionalism Norville Central teachers claim for themselves. The faculty see their professionalism as the outcome of hiring practices at Norville Central which have favored teachers with degrees in "real" subjects rather than education. They see themselves not only as teachers, but also as members of a larger community of

specialists in their fields. The statistics for Norville Central PhDs and MAs illustrate the school system's support of further education for its teachers and the faculty's commitment to their fields of expertise. The teachers talk about their school community in glowing terms which stress its intellectual and professional aspects, saying things such as: "Teachers came to Norville Central originally because they knew it was a place where they could try new things and explore," or "The Norville Central faculty is unusual, with a lot of independence about it. Many of the teachers are incredibly competent, with good minds; I find lots of interesting people to talk to here."

A steady machinery of rotation grinds along at Norville, forcing teachers to tackle new topics and types of students and preventing anyone from permanently claiming "choice" courses. The faculty is required to balance their schedules, teaching students from various grades and levels of ability according to the elaborate Norville Central tracking system. Although there is variation in procedure among departments, curriculum is generally decided upon jointly by the teachers themselves. In the mathematics department, for example, all of the faculty teaching the same course meet throughout the year and, as a team, determine the curriculum for that course. Final exams are written by these teams, a process which holds the teachers to the curriculum they have designed and places accountability within a realm of interlocking student achievement and peer pressure. As faculty members rotate course assignments each year, the membership of course teams changes, a process which provides flexibility and an avenue for new ideas. The overall curriculum for the mathematics department is similarly designed by a team of teachers who have had experience teaching a wide range of mathematics courses.

Everything must be negotiated at Norville Central and a lot of different people filling different roles become involved in even the simplest discussion. Faculty and administrators at Norville Central took a full year to write and agree upon a one page statement of the school's philosophy, a task which absorbed countless hours of many people's time but left everyone feeling that they had, at least, had their say. Consistent with the values of Norville Central this short statement of philosophy includes the point that "crucial to the success of our efforts is the freedom to teach unhindered by bureaucratic constraints and intrusions."

2: Arranging the Context for Dissemination

The entire first year of the laboratory site research at Norville Central was marked with tiny tiffs between ETC researchers and teachers. Norville Central *Supposer* users regularly declared their independence and consistently followed a pattern of asking for material support, such as computers, modems, and disks, while

rejecting any instruction they felt they could within the terms of their agreements with ETC. Once the *Supposer* project was "theirs" after the initial year of research, the relationship changed. The same teachers were delighted to have the researchers watch and applaud the way the tool was taking root within their system and enjoyed group discussions with researchers about how the *Supposer* could be used. If the relationship were clearly one between peers discussing a matter of interest to both, the enthusiasm of the Norville Central teachers was unlimited as they took their professionalism very seriously. Teachers bristled, however, when researchers suggested how to teach.

The lack of strong top-down structures at Norville made getting initial information about the *Supposer* to teachers a difficult part of the dissemination process. Planning for the spread of *Supposer* use at Norville Central began at the end of the first year of the lab site project. Mary, the mathematics department chairperson and one of three teachers who had worked with the *Supposer* on the lab site project, made a presentation of the *Supposer* in a mathematics department meeting. Several teachers who subsequently expressed interest in the tool took computers and *Supposer* materials home with them for the summer. The most telling statement about the relationship between the social structure of Norville and the spread of the *Supposer* was made by Mira in September: "I'll know how many teachers are interested (in learning to use the *Supposer*) when they sign up for lab time."

Meanwhile, Mira worked very hard behind the scenes to create that interest. She asked one of the *Supposer* researchers to give a very "mathy" demonstration of the *Supposer* during a mathematics department meeting at Norville. She specifically wanted a demonstration of the intellectual power of the tool in order to counteract the impression, which many mathematics teachers at Norville had, that the *Supposer* was something of a "touchy-feelly" toy. Mira had, in fact, rejected all offers by the researchers for assistance with the dissemination effort except for this particular use of their expertise. She felt that she had to be extremely careful to make it clear to the Norville teachers that ETC would not be involved in the opportunity to explore *Supposer* use which she provided. She believed that the teachers would have avoided any project which suggested outside manipulation of what the teachers considered to be "their" curriculum.

The other step which Mira took toward promoting the spread of *Supposer* use early in the fall was to find ways of "buying" time for teacher instruction and learning. One approach to this was asking the principal for a dozen of the substitute days which the school could distribute for teacher development. Another approach involved applying for teacher research and development grants, the money awarded

by those grants also being used to "buy" substitute teachers. Apart from the substitute days and the establishment of the computer lab, the Norville administration gave no formal support to assist the spread of *Supposer* use. They did, however, provide support in response to teachers directly asking for what they felt they needed, things such as typing assistance to make changes in exams that reflected shifts created by *Supposer* use, or extended copying privileges to duplicate*Supposer* materials for students. Near the end of the year one new *Supposer* user asked for a Professional Day which she used exploring uses for the *Supposer*.

Mira surveyed the teachers at the *Supposer* demonstration for the degree and type of their interest, getting a range of responses from great enthusiasm to total lack of interest. There were seven teachers who responded that they would like to experiment with the tool and Mira invited those seven teachers, plus two additional teachers who she believed would be interested if given an opportunity, to each take part in half-day training sessions on *Supposer* use in December. All but one of those nine mathematics teachers were currently teaching geometry courses, and that one teacher had taught geometry the previous year. There were nineteen teachers presently teaching geometry at Norville, including the three teachers who were already using the *Supposer* in their classes. Mira arranged for substitutes to cover a half day of classes for each of these teachers who wished to participate and for the two other veteran *Supposer* teachers, Amy and JoEllen, who would act as instructors with her.

3: Instructional Design

Mira and Amy led the first half of the session offered for instruction in Suppposer use, inviting the teachers who taught the first-year combined geometry-algebra course offered at Norville. Mira and Judith led the afternoon session for the teachers who taught the second-year course of the geometry-algebra curriculum. The format for both instructional sessions was modeled upon the method Mira used with the *Supposer* in her classroom. She introduced the tool by briefly describing several types of *Supposer* use, categories based upon distinctions between inquiry and application uses which had recently been suggested by the researchers. The teachers were then invited to take *Supposer* software, to select a computer, and to explore the packets of *Supposer* problems the veteran *Supposer* teachers had prepared for them. The *Supposer* problems that were distributed had been carefully selected out of the large collection supplied by ETC during the previous year; all three veteran *Supposer* teachers felt that such a mass of problems had been overwhelming in the initial stages of instruction. Mira and her co-instructors circulated around among the teachers, answering questions, and becoming involved in discussions about the *Supposer*.

An examination of which teachers chose to come to this in-service training in *Supposer* use revealed that half of the teachers attending were those newly brought into the high school from middle schools during the recent inclusion of the ninth grade in the high school, an adaptation to decreasing enrollment. These teachers were marginal to the existing social organization, both by their newness and by the relatively narrow range of high school mathematics subjects with which they had had experience. They knew that they were within a system which demanded course rotation and that they would have to expand their skills to cope with those expectations. They were also predisposed to value computer use more than many of the high school teachers because middle school teachers tend to use more hands-on "manipulatives" and, thus, lack much of the intellectual bias against such approaches, an attitude which was common among the Norville mathematics faculty.

The Norville team structures, which united faculty members teaching the same course, had an extremely important impact on what teachers attended the *Supposer* sessions and what they ended up working on during those sessions. For example, in the morning meeting two teachers, who both taught the lowest level of geometry classes at Norville, unexpectedly became interested in Amy's lower level problems, although they had originally assumed that they would use the tool in higher ability courses which each also taught. They spent the entire session figuring out how to adapt these problems to the ability level of their students, which was lower than that of Amy's class, and set in motion the process of using the *Supposer* with those students. They contacted the third team member who taught the same course, a teacher who was attending the afternoon session due to a second year geometry-algerbra course which she also taught. They also set up lab times for all three teachers' classes and asked Mira for the meeting time and office support they felt they needed. In the afternoon session, three teachers who taught the same course had all signed up to attend; at the last minute, realizing this, they pressured the fourth member of their team to attend, and Mira arranged for his classes to be covered.

In February a second series of two half-day *Supposer* sessions were held, while the teachers classes once again were covered by the substitute time that Mira had secured. In these sessions, three teams of teachers, each of whom had expressed interest as a group, were invited to attend and work together on adapting *Supposer* use and *Supposer* problems to the specific courses which they taught. Some of those invited were the same teachers who had attended the December *Supposer* sessions; four others were members of the same teams as those teachers or teachers who had not attended the December sessions although they had expressed interest in the *Supposer*.

In March Mira staged a third set of two half-day *Supposer* sessions. She invited members of three different course teams and a few individual teachers, offering instruction to two teachers who had not been at either of the previous sessions. All of the teachers who attended the instructional sessions engaged in energetic intellectual exploration of the *Supposer*, and most worked in a highly interactive manner with their colleagues. Rewritten *Supposer* problems, adapted by team members for the specific course which they all taught, were the most common concrete product of these sessions, but a great deal of serious discussion about the implications of using the innovation also occurred. To some degree, either as individuals or as members of a team, each of the new *Supposer* users adapted the *Supposer* problems they were given before using them. Left on their own to explore the *Supposer*, adapting the materials to suit their own use was the first thing most of the Norville teachers did. Discussion about the pedagogical and mathematical implications of *Supposer* use grew out of efforts to adapt the tool rather than preceding such activities. Some teachers also worked by themselves, pursuing their own questions; one teacher used the *Supposer* to try to duplicate for himself the experience of his students when they explored a new type of mathematics problem.

Three of the teachers who attended these sessions had committed themselves to trying out the *Supposer* during the previous spring. They all began using the *Supposer* in the fall in unison with two of the veteran *Supposer* teachers, Mira and Amy. One of these teachers was team-teaching with Mira, another was teaching the same course that Amy did, and the third taught the same course Mira did. Amy decided when in the structure of the course the *Supposer* would be used and what *Supposer* problems would be used, expecting the teacher she was instructing to use the same material on the same day. The new *Supposer* user team-teaching with Mira used the tool when and how Mira decided. However, Mira's instruction of the other new *Supposer* user was less directed than Amy's. Although this teacher taught the same course that Mira and her co-teacher did, she used a text book in her geometry-algebra course, which Mira and her co-teacher did not, and was not comfortable with the emphasis upon discovery which characterized Mira's style of teaching. Basically this teacher worked on her own, deciding when and how she would use the *Supposer*, with the help of *Supposer* problems which were made available to her, a number of pieces of time for *Supposer* exploration that were offered during the year, and many informal discussions with her *Supposer*-using colleagues.

All of the teachers learned to use the *Supposer* through informal discussion with their colleagues during whatever odd bits of time they could find, such as visits during study hall duty, exchanges during free periods, or talks over lunch. New *Supposer* users also observed veteran *Supposer* teachers using the tool in their classrooms. Faculty members commonly observe each others' classes at Norville, a

teacher generally being expected to observe a course he or she has not taught during the year prior to beginning to teach it. However, opportunities to observe one another's use of the tool were sometimes hard to find, as course scheduling had been arranged without any attempt to support *Supposer* dissemination. Who among the faculty was going to be using the *Supposer* only became apparent as the year unfolded and course scheduling had been completed before the year began. All of the new *Supposer* users reported that they needed more time to discuss the innovation with others using it, as well as more opportunities to observe one another's use of the tool. Use of the computer lab was also a scheduling problem at times. The new *Supposer* user being instructed directly by Amy taught her geometry class during the same time period in which Amy taught hers; they were never able to observe one another and could only do the same *Supposer* lab on the same days if a second Norville computer lab, used by many other departments, was free.

Once the *Supposer* had been absorbed into a few corners of the Norville curriculum team structure, the spread moved with an unexpected speed. Not only was the spread very rapid, but it was multidirectional. The structure itself shaped the spread, as individual teachers were pulled into exploring and using the *Supposer* by their colleagues with whom they had particular structural relationships. Spread of *Supposer* use was so rapid at Norville that third generation teachers, those instructed by teachers who had learned from the original ETC-trained teachers, had already appeared by halfway through the year. The decentralized structure of Norville allowed a flexibility in how the spread occurred, teachers simultaneously learning to use the tool in a variety of different ways, according to their own notions of what they wanted to use it for and their particular relationships with their colleagues. The same flexibility was apparent in the manner by which support for learning to use the *Supposer* was offered to individual teachers, or teams of teachers, in response to their indication of interest in the innovation.

Table I shows how *Supposer* instruction flowed through the team structures at Norville. Teachers of the same course are listed in the first column, the original participants in ETC's lab site project indicated by name and the others (who appear more than once if they teach more than one geometry course) indicated simply by a number. Their attendance at in-service workshops are indicated in the next columns and whether they ultimately taught with the *Supposer* is shown in the far right column. An asterisk identifies teachers who had recently transferred from the middle school to the high school, a characteristic which appeared to influence their receptivity to the *Supposer* innovation.

TABLE I
THE DISSEMINATION PROCESS AT NORVILLE CENTRAL

Teacher Teams[1]	In-Service Workshop Attendance			Taught with *Supposer*
	December	February	March	
Course A				
Mira	•	•	•	•
T1*	•		•	•
T2	•		•	•
Course B				
T3	•			
T4*			•	•
Course C				
T5*	•	•		•
T6	•		•	
T7		•		•
T8				
T9				
Course D				
Judith	•	•	•	•
T10	•		•	
T11			•	
Course E				
Amy	•	•	•	•
T12*	•	•		•
T13		•		
Course F				
T14*	•	•	•	•
T3	•			
T6	•		•	
T4*			•	•
Course G				
T5*	•	•		•
T14*	•	•	•	•
T1*	•		•	•
Course H				
Judith	•	•	•	•
T15		•		•
T16*		•		•
T7		•		•

[1] Teachers are listed by course and appear more than once if they taught more than one geometry course.

*=recently transferred from the middle school to the high school

Apart from the direct measure of *Supposer* dissemination at Norville indicated by teachers' use of the tool in their classrooms, there was evidence of indirect *Supposer* impact. For example, one teacher, who believed strongly that too much time was devoted to geometry in the total mathematics curriculum, attended the first *Supposer* session. He continued to explore the tool on his own for some months, but finally reached the conclusion that it did not add anything that he was not already doing in the geometry part of he courses. He was, however, intrigued by the use of conjectures with the *Supposer* and began to work out a means to use computer software to support conjecturing in algebra. Another aspect of *Supposer* spread not measured by the number of Norville teachers who began to use the innovation was the beginning of a spread to the other high school in Norville, Norville East. The computer coordinator for Norville schools told the mathematics teachers at Norville East about the *Supposer* use at Norville Central just as they had completed their new computer lab. They contacted Mira and asked for an introduction to *Supposer* use. Mira, Amy, and Judith offered a presentation on the *Supposer* at a mathematics department meeting at Norville East in May, providing the teachers with software and problems for a period of exploration after the discussion. In June mathematics teachers from the middle schools that sent their students to Norville were invited to the high school for an introduction to the *Supposer* and the Geometric *Presupposer*; they were given an opportunity to explore and discuss both pieces of software.

4: Structure and Fit

Because Norville Central does not have a strong hierarchical organization, it looks like a place of little or "loose" structure; yet, of the three schools involved in this study, Norville is probably the most highly structured. Its structure is a model of values found in the community of Norville, notions about the role of individuals in decision-making processes and the importance of academic excellence. The social structure of the school balances a weakened hierarchical organization with an elaboration of structure around aspects which affect academic achievement, equity, and ties among teachers. The structure at Norville made penetration of an innovation to the level of teacher involvement difficult, both because the school lacks easy top-down avenues and because Norville teachers tend to reject expertise from outside their system. However, once *Supposer* use reached the network of horizontal structures at Norville, teachers were rapidly drawn into learning about and using the innovation.

The Norville Central administration did not offer formalized training in *Supposer* use at Norville, just time to explore the tool and adapt it for use. The implicit trust in the Norville faculty's ability to control their own learning experience fit nicely with the pedagogical shifts to more student control in the classroom promoted by

Supposer use. The undefined time which the administration had contributed allowed for time to be used in a flexible manner in response to the new *Supposer* users requests, mirroring the interaction in the guided-inquiry style of teaching. In the same manner, the teams of faculty members working together to design problems for the course which they all taught resembled the teams of students who worked together to solve problems in the *Supposer* lab. There was a consistency between the type of innovation being disseminated and the manner in which the spread of *Supposer* use occurred at Norville Central.

III: ANALYSIS

A: WHO CONTROLS WHAT: A DIVISION OF LABOR

1: Context and Content

Many kinds of resources and assistance are necessary to support the spread of innovations in schools. Pat Cox has pointed out a distinction that is useful in considering the types of supports supplied, stating that "school improvement efforts need support at two levels: assistance focused on the *content* of the new practice, directed at the teachers who are implementing the innovation; and assistance focused on the *context* of the new practice, aimed at securing the necessary approval, resources, facilities, and personnel" (1983:13). The person within the school who can best arrange one type of assistance, may not be the person in the best position to arrange other kinds of support. Administrators, for instance, may be in the best position to provide contextual assistance that requires commitments of time and money over which they exercise control. They may not, however, be the best people to provide content assistance, which requires intimate knowledge of an innovation's implications for day-to-day management of curriculum, instruction, and classroom routines.

In Willis, for example, the school and district administrators provided substantial context assistance in the first year of this project. They quickly and efficiently established the computer laboratory, they provided the teachers with time to meet with researchers, and they manipulated course schedules in order to provide opportunities for the teachers to observe one another and discuss their experiences. Yet, in the second year of research, the teachers at Willis using the *Supposer* received less support in their efforts than they had in the preceding year. This change may have stemmed, in part, from the administration's apparent perception of the innovation as primarily technological rather then curricular or pedagogical. From this perspective, once teachers were familiar with the computer hardware and software, they did not need further support. This may explain why, during the second year,

the Willis teachers were not given the opportunities for instruction, discussion, and feedback which they felt they needed. Because the new *Supposer* user was a programming teacher already familiar with computer technology, she was assumed not to need extensive implementation assistance, although she had never before taught geometry. The hierarchical structure of authority at Willis meant that the Willis teachers were disinclined to ask for the support they knew they needed and that the administrators assumed responsibility for understanding what kind of support was necessary on both content and context levels.

In contrast, the Norville Central administration provided support on contextual matters and allowed instructional leaders to provide content assistance. The types of support they supplied ranged from establishing the computer lab to providing secretarial assistance in re-typing tests to encompass shifts in the curriculum created by *Supposer* use. And, most importantly, both building and district administrators offered free, undefined time which could be shaped to fit the content of the innovation by those who had experience using it and, therefore, better understood what was needed. The gift of unfettered time also meant that decisions about how to use that time could be made as the process unfolded and unexpected needs were discovered. At Norville the administration directly supplied only context assistance, allowing the teachers to define the types of content support that they needed.

It is not only that innovations need, as Loucks (1983) has pointed out, assistance and support by an array of players, but that a division of labor between what sort of assistance is supplied by what sort of "player" is essential. The different worldviews of teachers and administrators, which a number of researchers have outlined (Huberman 1983; Lieberman and Miller, 1986; Miles 1983), become crucial when considering innovations that are open to interpretation in their use. Teachers directly involved in an instructional innovation understand better than administrators what sorts of experiences and resources they need to adapt the innovation to their own circumstances.

Orchestrating a coherent combination of content and context assistance requires knowledge both of the innovation's particular implementation requirements and of the local school's particular norms and procedures for allocating resources. The value of a local facilitator (Loucks, 1983) who can bridge these two kinds of knowledge was apparent in the Norville case. In that school Mira had both classroom experience with the innovation as well as considerable capacity to tap administrative support at various levels in the school system. When the two kinds of knowledge are not united in one person, then a coordinated division of labor is needed between those who can best supply context support and those who can best offer content assistance.

2: Mandate and Choice

A basic dilemma in supporting teacher and school change involves selecting the most effective method for recruiting teachers' involvement. Huberman and Miles (1986) have suggested that innovation use which is mandated by a powerful central office can aid the institutionalization of that innovation. The ethnographic studies of Willis, Norville , and Culver raise some questions about this recommendation, particularly for the "guided inquiry" type of innovation studied here. Of the four school change "scenarios" described by Miles (1983:18) and by Huberman (1983:22-25), the most effective involved mandated use of the innovations with support from the administration, the second most effective involved teachers electing to use the innovation with administrative support, and the least effective was mandated use without support. Considering the risk of administrators' perception of an innovation leading to either no support or the wrong kind of support, then the dangers of mandating use of an innovation might seem to be as great as the potential rewards.

The administration at Culver offered more support for the teachers learning to use the *Supposer* than at either of the other schools; they arranged schedules, found stipends to encourage participation, and provided large pieces of time for instruction and discussion within a school-wide staff development structure. Within that program Culver teachers chose which staff development course they would take, but were required to take some course. Some teachers found the *Supposer* course the "least uninteresting" of their alternatives and enrolled merely to meet their requirement for training. The symbolic reminders of this forced choice relationship were always present in the *Supposer* course, where attendance had to be taken at all sessions and one teacher actually showed up with a written "excuse" from her headmaster for being late. The mandate seemed to undermine teachers' sense of commitment, as was evident when some teachers packed up their things and put on their coats before the classes ended. The formal staff development program, emphasizing the transmission of expertise, also promoted a passive role among the teachers. Overall the directive tone of Culver's in-service program was inconsistent with the shared authority implied by the innovation, and interfered with the spread of the collaborative guided inquiry approach.

An alternative approach to the mandate/choice dilemma was taken at Norville where teacher choice was maximized. School administration played no role in promoting the spread other than granting the number of substitute days and other kinds of support requested by the *Supposer* instructors. Mira used only indirect methods to recruit teachers, such as focused department presentations and opportunities to freely explore the software and *Supposer* problems. She knew these

approaches would address the Norville faculty's specific reservations about the *Supposer*. Teachers decided individually if they were interested in learning about the *Supposer* and were invited to explore it only if they indicated such an interest. Support for *Supposer* instruction and use was arranged in a flexible manner, as individual teachers or teams requested the specific type of help they wanted when needs arose. Teachers at Norville were given time to explore and discuss the use of the *Supposer*, working out the details of their own learning as it unfolded in a manner resembling the collegial exchanges which Little (1982) has suggested promote professional development.

These two examples support the findings of researchers who have emphasized the value of self-initiated learning (Havelock, 1969; Bang-Jensen, 1986) and suggest that administrative mandates may easily undermine the spread of innovations which depend on teachers' exercising independent initiative and judgement. No matter how responsive the staff development program at Culver was intended to be, its forced choice structure constrained the flexibility of the instructional design and left some participants passive and unmotivated. In the words of one Norville teacher, mandates to learn something mean that "it is being done unto you." Mandated training leads teachers to adopt a passive role, receiving information with little investment in using that information. The notion that it was a difference in teacher choice which influenced the difference in *Supposer* use between Norville and Culver is supported by data from within Norville. When asked what she would do differently if she could, Mira responded that she would not have invited the two teachers who indicated little interest in learning about the *Supposer* to the training sessions. Each of those teachers spent their time exploring *Supposer* use, but they were both passive in their approach and relatively uninterested in discussion of the tool's implications. They were two of the five teachers at Norville who received instruction in *Supposer* use but never used the innovation in their classes.

Variation in the method of teacher recruitment also indirectly influenced the way in which instruction could be carried out. Recruitment methods helped create real differences in the teacher audiences Greg and Mira addressed, which influenced how they taught others to use the tool. The mandated-choice program at Culver led some teachers to register for Greg's *Supposer* course even though they had never taught geometry or had not taught the subject in many years. Greg felt that the range of skills among the teachers in his class was so great that he needed to control what happened; he was never able to assume what they knew and did not know, as he could with his students. Because all of the the teachers in Mira's *Supposer* sessions were either currently teaching geometry or had recently taught geometry, she could make assumptions about what they knew.

Because most of the teachers attending the Norville *Supposer* sessions were currently teaching geometry, there was also an implicit assumption that they would be using the innovation in their classes between sessions. Cox has made another distinction relevant to this difference, saying that "of these activities (types of assistance), the most helpful for *teachers* were efforts to actually work through the specifics of using the practice in the classroom. This kind of assistance is very different from being passively trained in a workshop setting" (1983:12). By the second and third sessions the Norville teachers were able to engage in discussions in which they compared their experiences, offered feedback to one another, and asked the instructors specific questions related to their own experiences. The Norville instructional design allowed a "critical mass of users" to develop, "who can gain moral support and professional advice from each other, while also becoming local experts who can help pass on the skills to other teachers" (Loucks and Zacchei, 1983:29). Because only half of the teachers in the Culver *Supposer* course were currently teaching geometry, no assumption about actually using the innovation could be made and a cumulative sharing of classroom experiences was not as feasible.

B: INSTRUCTIONAL DESIGNS

1: Elements

Varied as the processes of innovation spread in the three schools were, they all tended to incorporate many of the same aspects. Formal workshops included such elements as didactic instruction about the innovation, opportunities to work through or to design sample student exercises with consultation from the instructors, and group discussions in which teachers compared experiences of teaching with the innovative approach. Other forms of instruction were provided outside of formal workshops to individual teachers or small groups. These included classroom observations, assistance in designing and preparing particular lessons, consultation about particular teaching experiences, and direct apprenticeships between two teachers. While the instructional designs differed significantly across the three settings, some elements appeared to be effective in all cases.

2: Impact of School

Showers, Joyce, and Bennet have concluded, after examining much of the literature on staff development, that "it doesn't seem to matter where or when training is held, and it doesn't really matter what the role of the trainer is - administrator, teacher, or professor. What does matter is the training design" (1987:79). The training designs in Norville and Culver were significantly influenced by the structures of the schools within which they occurred. Greg's design options were

limited and shaped by his need to utilize administratively designed staff development programs; Mira was able to construct a procedure which she felt best suited the specific innovation that the teachers would be exploring. The differences in design also reflected Greg's and Mira's roles within their schools, although their roles were not simply a reflection of their formal positions as junior teacher and department chairperson, respectively. Pamela at Willis was, like Mira, the mathematics department chair, but she had even less control over how *Supposer* dissemination would be carried out at Willis than Greg did at Culver. Sorting actors out by the positions they occupy is meaningless unless the roles associated with the position are understood within the context of the specific environments. The mathematics department chair at Culver, for example, would have been a poor choice as *Supposer* instructor because department chairs within that school do not teach; it was Mira's ability to change hats which she credits as being her greatest asset in carrying off the style of instruction she used. What mattered was not the role, but the power of the person doing the instruction to design and conduct the process in the manner he or she felt was most appropriate and to secure the support that was needed for the process.

At Norville Mira approached the instruction of her colleagues in *Supposer* use in much the same manner that she used the tool in her classroom, her teaching style being extremely discovery-oriented. She gave minimal instruction, but provided maximum support by getting substitutes to take classes so the teachers could explore the software individually and as groups, offering secretarial assistance in typing up new *Supposer* problems and new exams which resulted from adopting the tool, scheduling computer labs and giving assistance while teachers used the lab, and meeting other requests made by teachers as their task unfolded. There was consistency between her style of teaching, the objectives of the innovation, and how she instructed her colleagues.

The new *Supposer* users at Norville learned what the innovation was designed to do both from specific information about *Supposer* use and from the the experience of how their learning took place, a model of instruction which other researchers, such as Bird (1986), have also found effective. He has described one of the benefits of such an instructional design as being that "both the content and the procedure of the training were applied to the objective of the training. At any moment either the nominal content of the session or the trainer's procedure could be a topic for discussion" (1986:57). The *Supposer* instruction sessions at Norville were filled with exactly this sort of dual examination of both what was being said about the *Supposer* and how instruction in *Supposer* use was being carried out.

The circumstances of Greg's in-service course limited the extent to which he could incorporate inquiry experiences. Both Greg and Mira are very successful *Supposer* users in their classrooms and both, if asked, would stress the "inquiry" component of guided inquiry. Although the two teachers differ to some degree in their philosophies of teaching, the contextual factors already discussed helped to shape the different instructional designs which they adopted. The role which the Culver administration had taken in orchestrating staff development courses determined, indirectly, who was in the *Supposer* course and the atmosphere of the course, factors which constrained the instructor's choices.

3: Apprenticeship

One instructional design appeared in all three schools in spite of their different characteristics. This was a one-on-one apprenticeship relationship between an experienced *Supposer* user and a new teacher in which the relationship was based upon mutual respect and regular contact. This was the primary instructional design at Willis, occurred in two cases among the variety of approachs incorporated into Newton's instructional design, and was an adjunct to the formal staff development program in Culver.

At Willis teachers perceived of themselves as members of a cooperating community, so small that most interaction took place on a face-to-face basis. With only one experienced *Supposer* user and one novice, an apprentice approach to instruction, including tight coordination between the *Supposer* lessons the teachers were to present, made total sense. Trust, open communication, and cooperation were already in place and the instruction in *Supposer* use simply flowed along those lines. Two of the instructional situations at Norville followed the same pattern: one involved a new *Supposer* user who team-taught with one of the veteran *Supposer* teachers; the other involved a teacher who had taught for many years with a veteran *Supposer* user at a middle school where they often wrote their own class materials together. The specific nature of these relationships gave these Norville teachers the same sort of trusting attitude and frequent face-to-face contact that the Willis teachers had, in spite of differences in the size and complexity of their schools.

In Culver, the only teacher who used the *Supposer* in his classroom, other than the three teachers who had initially committed themselves to using the innovation, did not take Greg's staff development *Supposer* course. He taught in the same house as Greg, a unit within the high school specifically designed to encourage collegial exchange and collaboration. Just as in the cases of one-on-one instruction at Willis and Norville, *Supposer* spread flowed along pre-existing structural ties within Culver that brought teachers into regular, mutually supportive contact.

In these conditions, the new teachers willingly deferred adapting the tool to their own style until they were "on their own." The apprenticeship approach, particularly its tight control over how the new teacher uses the innovation, would seem unlikely to work without mutual trust and regular interaction. A problem that surfaced in all three cases of such direct training in *Supposer* use was that such small units of colleague instruction had difficulty tapping into the school's system of resource distribution in order to arrange the scheduling and time support that they need. This was the problem that worried a new *Supposer* user at Culver who wanted to instruct her colleagues during the next year within their house unit. She saw the advantages of utilizing existing collegial relationships, but was unsure how to arrange the necessary administrative support.

4: Efficiency

Teachers do not like taking time away from their classes as they are constantly working under the pressure of inadequate time for what they hope to accomplish with their students. The efficiency of the instruction that they receive is, therefore, of great concern to them. While it is deceptive to directly compare such aspects across schools, the variations in support offered, type of recruitment practiced, and instructional design between Culver and Norville Central did create differences in aspects of the dissemination processes which could be seen as indirectly reflecting efficiency. The small number of geometry teachers at Willis, the fact that *Supposer* use was mandated for those teachers, and the lack of a formalized instruction process there exclude it from such a comparison.

The amount of time teachers spent away from their classes in order to receive instruction on *Supposer* can be used as one indication of efficiency. Of the teachers who received formal *Supposer* instruction, the eleven Culver teachers spent 12 hours per teacher away from their classes, while the instruction time for the fifteen Norville teachers averaged only about 4.5 hours per teacher. The difference in time used appears to stem partly from the contrast between a teacher-directed, information distribution design, which attempted to give teachers as much of what they would need to know as possible, and an exploration-based design, which attempted only to get teachers started using the tool, adapting it, and discussing its implications.

Another measure of instructional efficiency that could be considered is the percentage of teachers receiving instruction who actually used the *Supposer* in their classrooms. Table II summarizes these results for Norville and Culver. Of the fourteen Norville geometry teachers who were instructed in *Supposer* use, nine used the innovation in at least some of their classes. (A fifteenth teacher also participated in the training, but did not use the *Supposer* because he did not currently teach

geometry.) Only three of the eleven teachers who attended the *Supposer* course at Culver used the *Supposer* in their classrooms, but this statistic must be considered within the context of the collection of teachers in the course. Five of the them had no opportunity to use the tool as they did not currently teach geometry. The three teachers represent fully half of the six geometry teachers who participated in the training. Use, in itself, is a rather vague concept and certainly needs to be further qualified by matters such as how much use and how sophisticated the use. Despite this vagueness, recruitment policies and resulting instructional designs do appear to affect this aspect of the efficiency of the instructional program.

TABLE II

SCHOOL	RECEIVED TRAINING	TAUGHT WITH SUPPOSER	% TRAINED WHO THEN TAUGHT WITH SUPPOSER
CULVER teachers	6 of 13 geometry teachers=46%	3	3/6=50% of trained geo.
	5 non-geometry teachers	0	3/11=27% of total trained
NORVILLE	14 of 16 geometry teachers=87%	9	9/14=64%

A third approach to efficiency of dissemination is a consideration of the percentage of geometry teachers in the school who received training in *Supposer* use. The course selection approach, embedded within Culver's staff development program, exposed six of the thirteen geometry teachers (46%) in that school to the *Supposer*. At Norville the combination of individual choice and links provided by the team structures eventually led fourteen of the sixteen geometry teachers (87%) in the school to receive instruction in *Supposer* use.

C: THE PROCESS OF LEARNING

1: Using and Telling

The debate about the role using information plays in learning is grounded in very old and powerful assumptions about the nature of knowledge. For many years archaeological evidence that our early ancestors' ability to stand upright, and therefore use their hands to manipulate tools, preceded enlargement and development of their brain was rejected. The dominate belief was that the species became smart and then, as the result of that increased intelligence. learned to use tools. The idea that using tools made our ancient ancestors become smarter has only recently been

accepted as a more accurate reflection of the process. Jumping a few million years, Lampert reports that "although it would be reasonable to imagine that changes in teaching practice follow changes in teacher beliefs and attitudes, the *Supposer* innovation did not work that way. Teachers' beliefs and attitudes changed over their course of their years' work with the *Supposer* , being strongly affected by what they observed their students doing as they used these new teaching tools" (1988a:11).

What shaped the differences in instructional design between Norville and Culver were not only the social structures of the two schools, but also a difference in underlying philosophy about using an innovation versus telling people about it. Mira first involved teachers in using the innovation, and dealt later with whether their ways of using it incorporated the pedagogical shifts it implied. Greg was more directive in his *Supposer* course in part because he wanted "to make sure that they understood the higher order pedagogy it (the *Supposer*) addressed". One approach began with use, assuming that knowledge would grow out of mulling over the experiences encountered during use of the innovation; the other approach included more telling the teachers about the knowledge embedded in the innovation, assuming that they could then make better use of the tool. The former design is more consistent with the educational philosophy underlying the innovation itself which assumes learners gain from constructing understanding from their own experiences.

Beyond the immediate changes the innovation created for students, the fact that teachers are actually using the innovation sets in motion the potential for an evolution in the teacher pedagogical styles. In addition to the changes in their classrooms that teachers respond to (Lampert, 1988a), opportunities exist for teachers to observe other teachers using the innovation in ways they might not have considered previously. Their use of the tool in correspondance with others also trying it out can increase the need to re-think what is being taught and why. Just as having hands free to use tools created the need to think about how to use the tools and to develop a means for communicating that knowledge for our ancestors, use of a complex enough tool can trigger the need to think about its implications and to communicate with others about those implications.

2: The Role of Adaptation

Simply using a tool is, obviously, an insufficient measure of success, in spite of the powerful role it may play in introducing change. Innovations are generally designed to promote very specific changes which teachers using the innovation tend to make to varying degrees. The case for mutual adaptation was proposed in the literature on change in schools quite a few years ago (Berman and McLaughlin, 1974). Since then, however, research has become increasingly concerned with the

dilemma posed by the need teachers express for adapting innovations to their particular teaching situation and the versions of the innovation resulting from that adaptation which researchers often see as "watered-down" and incapable of doing what they were designed to accomplish (Crandall, et al., 1982; Elmore & McLaughlin, 1988).

At Norville, where teachers were simply given *Supposer* software and problems, almost the very first thing that the majority of those teachers did was begin to adapt the *Supposer* problems for the specific geometry course which they taught. At Culver teachers were offered a course on the *Supposer* that gave information about the tool but offered little opportunity for teachers individually to adapt the *Supposer* to their classroom practice. The Culver teachers who did attempt to use the*Supposer* in their classes found the course was often too generalized and abstract. They tended to judge both the instruction and the innovation as not "practical," meaning as Doyle and Ponder (1977) discuss that it was not directly applicable to their classroom work. At Willis the new *Supposer* user indicated her intention to adapt the *Supposer* materials during the next year. The need teachers express to adapt innovations is obviously deeply felt and influences how they respond to instruction in the use of new tools.

One reason teachers give for adapting innovations is to make them address their students' needs. Like many high school courses, most geometry courses taught by the teachers in this study were divided into tracks for students who were perceived to have different ability levels. Most of the teachers felt that the *Supposer* improved geometry learning in different ways for sudents of different ability levels and that these various ways did not seem to be notches on a linear continuum. Instead they believed that particular aspects of the tool were more or less valuable for different types of students. They felt that the benefits of *Supposer* use which the researchers were most interested in promoting — such as increasing the students' active role in a process of induction, creating conjectures about mathematics, and understanding why proof is necessary in geometry — were realized more for high ability students. For lower ability students, they felt the Supposers' advantage derived from aspects of the *Supposer* such as hands-on practice and use of a status symbol computer, both of which tended to motivate the students, and its presentation of visual material which benefitted those with less comprehension of verbal and symbolic information.

For the teachers the process of figuring out how to adapt the *Supposer* to their specific geometry course was of paramount importance, although the force of this focus varied among the schools. At Culver, where course rotation was minimal, teachers were more tightly focused upon the specific uses of "their students" than at Willis, where mathematics courses are not tracked, or at Norville, where mathematics

faculty simultaneously teach a variety of ability levels and course rotation is extensive. But all of the teachers said the primary reason they had to adapt the *Supposer* problems was to accommodate the different needs of their students, although most of them admitted that they also needed to re-write things into their own "style."

The matter of "style" is much more significant than the term implies and probably cloaks what researchers generally mean by pedagogy. At Norville a team of teachers who all taught the lowest ability level of the geometry-algebra courses re-wrote the problems which Amy, who taught the next highest ability level students, had used. Instead of making the lessons more structured as many teachers tend to recommend for lower ability students, thereby stressing the "guided" part of guided inquiry, they actually made the conjecture-producing part of the exercise less structured than Amy had for her higher ability students. Perhaps the teachers' preferred teaching style drove this pattern of adaption more than student need. The opposite process also occurred at Norville with the most accelerated group of geometry students. Mira and her co-teacher, who both believed strongly in the importance of the inquiry, used the *Supposer* in an extremely unstructured manner. Other teachers tended to attribute their style to the freedom which the ability of their ninth grade honors class allowed. Yet the Norville teacher who taught the other ninth grade honors class led her students into the *Supposer* lab only after she had fully introduced the concepts in classroom that she felt they would need to make the experience valuable. She re-wrote Mira's *Supposer* problems to provide greater structure for her students. Teachers' need to adapt innovations appears to stem at least as much from their preferred teaching styles and their values about how to best teach students as from perceived variations in "their" students' ability.

Among the teachers adapting the *Supposer* for their own use, some ended up using a version that should be considered trivialized or "watered-down" in terms of the researchers' original desire to promote inquiry-based learning. But, in a number of cases, colleagues trained by veteran *Supposer* users adapted their own use of the tool to be closer to the original intention of the researchers than were the uses of their instructors. This is an important sign that, once off the mark, things will not necessarily deteriorate further. It is also evidence that teachers do not always "naturally shy away from the more demanding and adventurous components" (Huberman, 1983:24) of an innovation when allowed to adapt it to make sense within their own scheme of things. These cases also run counter to the assumption that adaptation always means a loss in terms of the original intention, the continued process of mutual adaptation leading, over time, to the "inevitable reduction in the integrity of the innovation" (Bird, 1986:47).

The research literature in education has tended to focus upon the political reasons teachers adapt materials as part of a bargaining process with administration (Crandall, 1983), upon the sense of ownership which the process of adaptation promotes (Berman and McLaughlin, 1974), and upon the increased fit between innovation and environment which results from such adaptations (Huberman, 1983). These reasons seemed to play only a minor role in why the teachers felt they needed to adapt *Supposer* use, a situation which may exist with other innovations that require interpretation and cannot be simply applied in a mechanistic manner. What became apparent in watching teachers adapt the *Supposer* to what they saw as their students' needs and their own styles of teaching, was that this process, in itself, forced a re-evaluation of geometry teaching that those teachers found exciting, frustrating, and, on the whole, very beneficial. In order for teachers to re-create material so that it fits their notions of what is important, they have to understand the implication of the choices being made. Due to the depth of understanding and thought such a process requires, the act of adapting does something which cannot be accomplished by simply telling teachers how they should use the innovation.

For simple innovations that require little interpretation by the teacher in their use, adherence to strict guidelines may be an effective way to insure that the original direction of the innovation is not lost. But for complex innovations which require a great deal of interpretative skill, encouraging teacher adaptation may be the best approach, as mechanistic use of the tool may destroy its original objective. Insistence upon a set use for a tool such as the *Supposer* may protect against deteriorated and expedient uses which dilute the potential impact, but may also prevent the serious re-thinking of the teaching process which the innovation is designed, in part, to generate. The goal of *Supposer* use for students is to increase participation in their own learning process; teachers can be expected to benefit in creating their own understanding of what they are doing in exactly the same manner that their students do. Recent research by Elmore and McLaughlin (1988) points out that adaptation is fundamentally a matter of active problem-solving, teachers developing an investment in innovations by applying their own skills to creating the changes.

D: STRUCTURE AND FIT

While recent research in education has agreed upon the need for greater professionalism among teachers, it seems oddly split in the focus it accepts for how to achieve that result. One school of thought appears to define "professional" in terms that emphasize expertise and skills. This perception of professionalism stresses recommendations for increased training of teachers, both through staff development programs and through reformation of the initial education of teachers.

Another notion of what "professional" means focuses upon control over one's work and work environment, a perspective that has resulted in recommendations for increased horizontal ties among teachers and greater power for teachers in decision making processes. While it is clear that professionalism involves both expertise and control, our current cultural notions about teaching, teachers, and schools tend to force these recommendations into an oppositional relationship. As long as the expertise, which teachers are seen as needing, is perceived of as existing with others, who have more power and status relative to teachers, then it is difficult to recommend teacher control of their own "development." On the other hand, if teacher control is perceived of as simply removing constraints on teacher decisions and allowing teachers to manage their own continuing education, then it becomes difficult for innovations in their field to reach teachers, who have little time to explore current research findings or to secure necessary resources to conduct elaborate research and development activities themselves.

As *Supposer* use had originally been introduced into all three schools by Harvard University's ETC, variations in assumptions about professionalism among the schools influenced their responses. The school where initial implementation was the easiest was the one most willing to value and accept outside expertise and that had the strongest top-down channels through which to funnel the innovation. It was in this school, however, that the teachers lost most when ETC's direct support ended. In the school where ETC's initial entry was the most strained, because recognition of outside expertise did not mesh well with the school's values and because its top-down structures were minimal, *Supposer* use spread rapidly among the faculty after ETC was no longer involved. The role of outside agencies such as ETC can, therefore, vary according to the nature of the school in which it is attempting to introduce innovations.

Concepts about professionalism are often expressed in the structures of decision-making, control, and social interaction of a school. For example, the school that saw teachers as needing new skills and saw those skills as located with outside experts used hierarchical structural pathways for transmitting those skills to them, mandating Supposer use for all geometry teachers. Teachers' control over the conditions of their own work was not a dominant value in that school, a fact reflected in the teachers' sense that they lacked avenues for securing the time and scheduling arrangements which they felt that they needed. In contrast, the school where teachers were seen as primarily needing only an opportunity to perfect their own practice offered few structural means for outside experts to reach the teachers. In that school, however, once the innovation had achieved a foothold, teachers were able to use a number of pathways to secure the type of support they decided they needed. Differing school values create a variety of structures in schools. These different

structures have implications for introducing and disseminating innovations, making certain strategies appropriate and certain activities easy in one place that may be inappropriate or difficult in another.

The structure of events, processes, and social relationships in a school not only reflects underlying values and ideologies, such as attitudes about professionalism, but determines how things can and do happen. Elmore and McLaughlin (1988) have pointed out that reforms succeed to the degree that they are adapted to and capitalize upon the existent characteristics of the school. Recognizing school structures and utilizing those systems makes the process of implementing and spreading innovations more successful. One of the main differences in the forms of dissemination that were offered at Norville and Culver was that the Norville instructional design utilized already existing relationships among teachers, such as the course team patterns, while the type of instruction offered at Culver cut across the existing structures, such as the house units. The speed with which Supposer use spread at Norville was, in part, due to the decision to take advantage of existing structures rather than trying to construct a new system for dissemination.

The dissemination process appeared to be more successful not only when it tapped into existing school patterns, but also when it was structured to fit the particular needs of the innovation. The specific innovation examined in this research required a great deal of discussion, experimentation, and feedback among those involved. Consequently, the composition of the group of teachers receiving instruction was important, as these are practices which happen most easily within a group that shares specific skills and interests. The type of recruitment and the organization of instruction at Norville were selected by a teacher who understood this innovation as a technique for working with and thinking about information. She had sufficient control over the dissemination process to provide a structure that promoted these activities. At both Culver and Willis the innovation was perceived of as additional information teachers needed or should have by those who controlled the dissemination process. The nature of the relationships among the teachers being instructed were not seen as important as the goal was perceived of as each teacher's individual acquisition of expert information. Within that conceptualization, an approach to dissemination that maximizes the number of teachers who will receive that information makes sense. The forms of recruitment and instructional design adopted in these two schools treated teachers as unrelated and homogeneous. As in the case of underlying concepts about the nature of professionalism, the concept of what the innovation was about affected the structure of dissemination selected. If the innovation was seen as simply involving the acquisition of additional information, then the spread design could ignore the nature of relationships among those being instructed. If, on the other hand, the innovation was perceived of as a technique for

handling information, then the community within which instruction would occur became the most significant aspect of the process, as creation of the context within which those skills could be practiced was essential.

There is another, and perhaps the most important, way in which the understanding of structural relationships and processes surfaced in this research. The manner in which innovation dissemination is organized can influence not only teachers' short-term acquisition of new knowledge and skills, but also such long-term goals as professionalism among teachers and more effective schools. School and dissemination structures are not only models for how things happen, a system for how to get things done, but also a model of underlying values and concepts, an ideological scheme of how things should work. Due to this dual role, structural forms can act as the link between values and actions. The link operates in both directions, the values of the community being reflected in the structures adopted and the structures which shape activities becoming the basis for values.

Social science research has taught us that it is easier to change how people act than how they think. Structural changes can provide a useful connection between changes in behavior and in thoughts. This conjecture was confirmed by activities at Norville the year after the spread of Supposer use reported here. During the following fall, there was a sharp increase in the number of mathematics teachers observing one another's classes. The use of a dissemination pattern that focused upon teacher interaction had strengthened the structure of horizontal ties among the teachers during the process, providing a model for tackling other subjects. Parish and Aquila have pointed out the importance of designing innovation support in a manner which "promotes teacher networks at the same time instruction happens. Promoting innovations in this manner will help schools to evolve into different organizations. A series of such changes will produce a very different school structure" (1983:32). Changing the structure of how things happen in a school can lead to more far-reaching and long-term changes in the underlying values and concepts of the people in that environment.

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