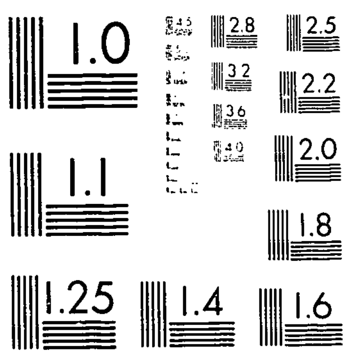
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ABSTRACT

The research presented in this report investigated the critical factors that affected the decision to abandon or replace a curricular innovation in one elementary school. The specific innovation examined in this research is called developing mathematical processes, which emphasizes process and induction rather than computational skills. Although the principal is the primary determiner of school policy, there were at least three other variables that significantly affected continuation of this innovation: the actual and perceived fit of the innovation with the developmental and learning characteristics of the student, the students' test scores on standardized mathematics tests, and the difficulty students who transferred from other schools had with the program. The interaction among these elements stands as a useful example of the importance of attending not only to the specific values of the variables over time but to the dynamics that produce those values. Thus, the findings suggest the use of long time-frames and attendance to multiple and reciprocal causes. (Author/JK)

Technical Report No. 542

A SYSTEMS DYNAMICS MODEL OF IMPLEMENTATION OF AN INNOVATION

by

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Report from the Project on
Studies of the Implementation of Individualized Schooling

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- providing assistance to educators which helps transfer the outcomes of research and development to improved practice in local schools and teacher education institutions

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ABSTRACT

The Studies of Implementation was proposed as a 3-year longitudinal investigation of planned educational change. Specifically, the research was concerned with the process by which an innovation was implemented into and became a pattern of individualized schooling.

The Studies of Implementation work group documented and analyzed the innovative behavior of 13 elementary schools. Ten of the research sites were located in Wisconsin and three in a large urban area outside of the state.

Using a combination of quantitative and qualitative techniques, data were collected to answer four research questions:

1. What factors affect the decision to adopt an innovation (the IPM)?

2. What factors affect the rate of implementation of an innovation (the IPM)?

3. What factors affect the adaptation of an innovation (the IPM)?

4. What factors affect the decision to abandon or replace the innovation (the IPM)?

The research reported in this technical report investigated the fourth research question. Specifically, the purpose of the research was to learn about the dynamics of curriculum change (i.e., the use of

DMP) in Mercury School and to depict this in the form of a continuous simulation model.

In the analysis, three elements were identified as critical in the failure of DMP to sustain itself at Mercury School. These included the actual and perceived fit of the innovation with the developmental learning characteristics of the students and the relationship between the school's curriculum and that of the rest of the school district. Carriers of the school district norms and practices in the situation studied were the standardized tests and the effects of transfer students on the teachers who had to deal with them. Our analysis suggests that to the extent that the innovation is inconsistent with important norms and practices in the school district, it may, by its very implementation create the pressures that ultimately lead to its discontinuation.

CHAPTER 1

INTRODUCTION AND BACKGROUND

The Studies of Implementation was proposed as a 3-year longitudinal investigation of planned educational change. Specifically, the research was concerned with the process by which an innovation was implemented into and became a pattern of individualized schooling. The research identified those factors or conditions which promoted or retarded change in schools and related the factors to the modifications they fostered.

Overview of the Research

The Studies of Implementation work group documented and analyzed the innovative behavior of 13 elementary schools which had chosen a course of planned educational change. The instructional innovation which all 13 schools had chosen to implement was the Instructional Programming Model (IPM), the central concept of the more complex innovation, Individually Guided Education (IGE).

The population of the research sites was originally limited to Wisconsin IGE elementary schools. The population of such schools was stratified by the number of years a school claimed to be an IGE school, whether the school was located in a nonurban or an urban (Milwaukee) area, and by use of the curricular products developed at the Wisconsin Research and Development Center. With one exception, potential research sites were randomly selected from these strata. The exception involved the deliberate selection of a nonurban school which had just made the decision to implement the IPM. Ten Wisconsin research sites were selected.

A troublesome feature of the sampling plan was whether the urban schools which, by necessity, all had to be located in Milwaukee, were representative. A decision was made to obtain three additional urban sites outside of Wisconsin to provide a point of comparison. All three sites had chosen to adopt and implement Developing Mathematical Processes (DMP), a curricular product based on the Instructional Programming Model. Thus, the sample was expanded to include 13 schools. Table 1 summarizes the salient characteristics of the research sites.

Using a combination of quantitative and qualitative techniques, data were collected in the 13 sites to answer four research questions.

1. What factors affect the decision to adopt an innovation (the IPM)?

2. What factors affect the rate of implementation of an innovation (the IPM)?

3. What factors affect the adaptation of an innovation (the IPM)?

4. What factors affect the decision to abandon or replace the innovation (the IPM)?

The research presented in this report investigated the fourth research question--What factors affect the decision to abandon or

Table 1

Description of the Thirteen Research Sites at the Time of Selection

School Name	Number of Years Using the IPM	Setting	Number of Students	Number of Teachers	Use of R&D[a] Curricular Products
Lewis	Less than 1	nonurban	437	18	NU
Star	1	urban	525	20	WDRSD
Arrow	2	nonurban	315	13	WDRSD
Mercury	4	urban	468	18	DMP
Meadow	6	nonurban	97	5	WDRSD
Sawyer	7	nonurban	350	13	WDRSD
Rise	7	nonurban	395	14.5	DMP;WDRSD
North	7	nonurban	285	12	DMP
Davis	7	nonurban	465	17	NU
York	4	urban	500	15	WDRSD
Canal	2	urban	620	25	DMP
Ware	2	urban	750	40	DMP
Miller	2	urban	507	25	DMP

[a]NU = Not Used.
DMP = Developing Mathematical Processes.
WDRSD = Wisconsin Design for Reading Skill Development.

Source: Davis, W., Klenke, W., & Barrows, L. (1979).

replace an innovation? Data were collected at one of the urban sites, Mercury School, on the decision to discontinue use of Developing Mathematical Processes (DMP). This report contains an interpretation of these data.

The Nature of the Problem

There is still much to be learned about the dynamics of curricular change in public schools.

Early research on educational innovations was rooted in the tradition of agricultural sociology (Havelock, 1969, pp. 10-14, ff). It dealt with the formal adoption of new programs in schools by superintendents and school boards. The research identified the personal characteristics of individual adopters and categorized them as innovators, early adopters, early majority, late majority, or laggards (Rogers, 1962).

In the 60's, investigations of educational innovations were based mainly upon earlier studies about influential individuals. Researchers of the Research, Development, and Diffusion model and social interaction perspectives studied networks of interpersonal relationships. Terms such as "cosmopolitans" and "locals" marked the writings of scholars predominately concerned with the diffusion of externally developed innovations among individual adopters. Organizations, such as schools, were treated implicitly as individuals, consistent with what Graham Allison later called the "rational actor paradigm" (Allison, 1971).

Not until the late 60's and early 70's did theorists distinguish between the dynamics of adoption among individuals and those in organizations. Much of the research of the 70's has studied the processes of implementing innovative practices in schools (Gross, Giacquinta, & Bernstein, 1971). Some investigators have emphasized the importance of environmental influences upon the course of events relevant to introducing new programs and policies (Baldridge, 1972).

Research to date has provided useful information about several elements of the innovative process. These include knowledge of the personal characteristics of individuals engaged in adopting and promoting new practices, knowledge of the sociometry of diffusion and the role of change agents and influentials, a sense of the "stages" of innovation, and information about specific factors and techniques which can act as barriers to and facilitators of planned change (Havelock, 1969). Significant ethical and philosophical issues have also been discussed as well as the particular characteristics of schools which define the climate for introducing new practices (Bennis et al., 1976; Giacquinta, 1973; and Pincus, 1974).

Needs for New Research Directions

There is a need at the present time to move research on educational innovation into new directions.

A significant statement made about American schools is that they do not change very much in fundamental ways over years of observation (Goodlad, Klein, & Associates, 1971). Understanding the dynamics of stability and change in schools seems to require going beyond the study of novelty.

This implies a need to move away from the concept of innovation simply as "something new in the school" to a conceptualization which permits research to concentrate on shifts in the regularities of instruction along dimensions which can be tracked over long periods of time. To do this effectively, it will be necessary to transcend the current focus upon adoption and implementation, to place increasing emphasis upon the pervasive phenomenon of discontinuation, and to study more and more the full-life cycle of major dimensions of schooling. Thus, for example, it is important to study dimensions such as individualization of instruction over periods of 20 to 30 years or longer. This implies seeing specific innovations in a larger context.

A major theme of change theory has been its concentration upon managerial practice. Implicit assumptions have been that change is good (those who oppose it have been commonly characterized as "resisters" and "laggards") and that the primary reason for the failure of innovations is ineffective leadership.

A fuller theory of change recognizes the existence and legitimacy of multiple constituencies holding diverse value positions. It recognizes that decisions in complex social systems are keyed to a variety of pressures and cross pressures which constitute the basis of rational human behavior.

When the climate for change is right, effective management may be critical to success or failure, but the case literature (Baldridge & Deal, 1975) amply demonstrates that long-term change is typically more than a matter of simple management; it is significantly related to deeply held values and to the judgments of people with different ideas about the costs and benefits of proposed new programs. It seems important for research to discover the dynamics of cross pressure which transcend technical managerial practice and which define the context and limits of leadership in schools.

Finally, there is a need to move beyond the limitations of the traditional statistical paradigm. Single-equation hypothesis testing focuses analysis upon discrete, additive effects. The view of the world which this paradigm implicitly espouses is essentially fragmented.

Longitudinal studies of covariance have been useful in describing succinctly important observed behaviors. Such studies depict relationships among variables which constitute what can be described as whole system behaviors. Such behaviors are the result of the interaction over time of complex structural relationships. New directions in research should include systematic techniques for depicting, examining, and assessing the variables which may cause the observed trends and correlations.

This suggests the need to employ methods which take the study of educational change beyond simple verbal descriptions or traditional statistical analyses. Fortunately, the need coincides with an increasingly sophisticated technology which makes this research possible (Forrester, 1968).

The Purpose of the Research

The purpose of the research reported in this paper was to clarify the dynamics of curriculum change in one elementary school and to relate our findings to their behavioral implications.

Specifically, the goal was to acquire sufficient knowledge of the critical variables and their relationships in order to formulate a continuous simulation model of curriculum change in that school. We anticipated that the model would be capable of reproducing the observed historical trends associated within the time frame of the curriculum innovation we were studying and that the assumptions represented in the model would seem plausible to the teachers and principal who had experienced the history of the innovation.

This paper reports the information acquired about the critical variables affecting the decision to discontinue use of a curricular innovation in one school. More specifically, Chapter II presents a narrative of the methodology used in the study and a description of the research setting and the innovation. Chapter III contains the data generated from the research in the forms of verbal description and model outpu.. The final chapter, Chapter IV, contains implications of the study.

CHAPTER II

METHODOLOGY

In this chapter the methodology, the research setting, and the innovation are described. Included in the discussion of methodology are data collection and analysis procedures including initial data collection, analysis, follow-up data collection, formulation of the model, and final feedback and refinement of the model. Descriptions of the setting and innovation are limited to the critical attributes of each as they relate to this research.

Data Collection Procedures

The project staff decided to apply the perspective and techniques of System Dynamics (Forrester, 1968) to the study of 1 of the 13 research sites. The idea was to discern and model the feedback systems which determined the course of an innovation over time. It should be clear to the reader that the purpose of the study was to understand and describe the dynamics of curriculum change, not to assess the effects of instruction upon student learnings. To fulfill this purpose it was necessary to collect information from knowledgeable participants toward several ends:

1. To establish consensus about the pattern of level of use of DMP from 1974 to 1980.

2. To reach agreement about the variables which contributed to the history of DMP in the school.

3. To reach agreement about the relationships among those variables which structured the interactions of response and counter-response accounting for the implementation and eventual discontinuation of DMP over time.

Certain assumptions underlie the approach the project has taken to collect and analyze. Primary assumptions from the history and philosophy of science are that knowledge is always subjective (Hanson, 1958; Kuhn, 1962) and that intuition plays a necessary role in the theoretical interpretation of data (Polanyi, 1969). Further, the major portion of knowledge available about organizational dynamics is neither quantified nor even written. Rather it is in the heads of people with significant experience in particular organizations.

Based upon these assumptions, an approach was developed by the project staff which is similar to a police artist model. In this approach to data collection, people who have seen "the criminal" are asked to provide information about the criminal's appearance.

This approach relies upon the dynamics of feedback and consensus. Information is sought from multiple observers and a process is established whereby there is an ongoing information exchange between the artist and the witnesses. The central role in this process of information exchange is played by the sketch. As the drawing unfolds, witnesses respond to it and changes are made incrementally by the artist in the course of what becomes a series of successive approximations toward consensus. In an analogous manner, the police artist paradigm guided the data collection process employed in the Mercury School.

Initial data collection. Initial data were collected in a series of recorded hour-long retrospective interviews with the principal of the Mercury School and 11 of the 13 classroom teachers. Individual teachers were interviewed once each, some singly, others in pairs. The principal was interviewed alone on several occasions.

Interviews were usually held by all three members of the project staff. Substitutes were provided at project expense to free teachers for the initial interviews during regular school hours. Infrequent differences in factual recollection were reconciled by reference to the tapes and transcriptions of the interviews, and, if necessary, by rechecking with the teachers or principal.

Initial interviews were also held by the entire project staff with the principal and two unit leaders of what we have called Jupiter School. Jupiter School is also an IGE school which has used DMP for a comparable period of time, and it is located in the same school district as Mercury School. However, in Jupiter School, DMP has been implemented only in the primary grades where there continues to be strong support for DMP.

Analysis and follow-up data collection. Central to the police artist methodology is the concept of feedback and refinement. Following the initial interviews in Mercury School, a meeting was held with the principal and almost all of the faculty present. Teachers were paid by the project for participating in sessions held prior to and after regular school hours. At this first feedback session, the project staff shared with the teachers their knowledge about the course of DMP over the period to that point in time. Consensus was reached with the principal and faculty about the shape of a graph depicting the average level of use of DMP in the school between the 1974-1975 and 1979-1980 school years. This graph came to be called the "reference behavior graph" because it constituted the reference behavior which the study was seeking to explain. The reference behavior graph is displayed in Figure 1.

Formulation of the model. During the next 2 to 3 months, the project staff worked to clarify their theoretical assumptions about the factors and relationships which explain the reference behavior. As a central part of this process, a continuous simulation model of mathematics curriculum change at the Mercury School was constructed at the Boston University computing center. The specific modeling approach is called System Dynamics. It was developed by Forrester (1961) and employs a compiler program called Dynamo II. Other versions of the compiler, including Dynamo III and Mini-Dynamo are currently available. (Information may be obtained from Push-Roberts Associates, 5 Lee Street, Cambridge, Massachusetts).

The formulation of this computer model was the project's most sophisticated analog to the police artist's sketch. The model has made it possible to test the behavioral implications of emerging theoretical assumptions. The twin objectives of the test procedures were to discover how credible the assumptions of the model are to

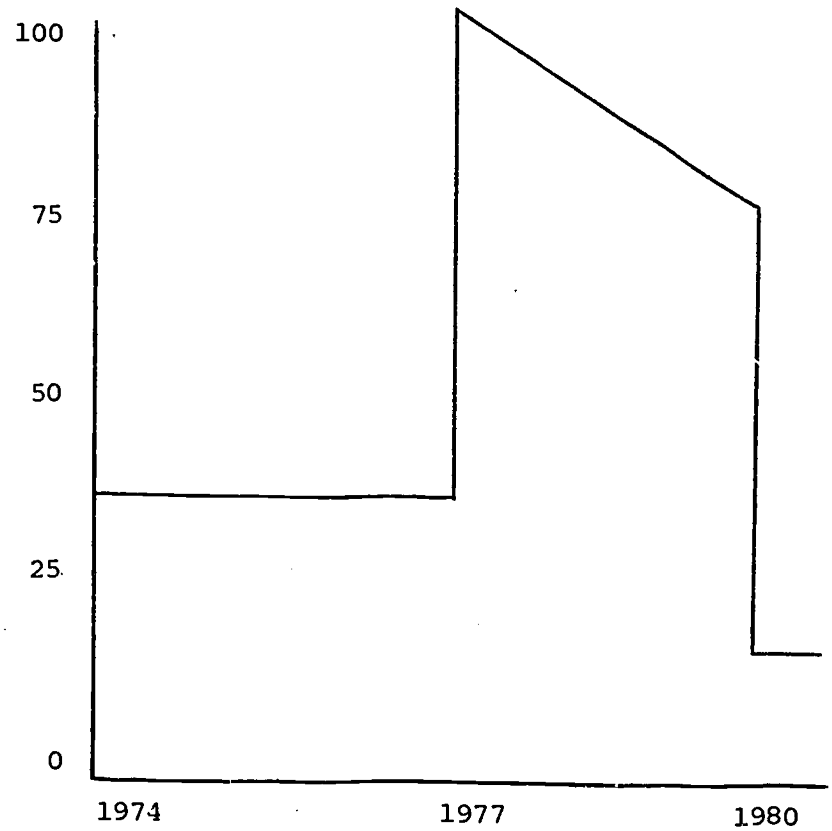

Figure 1. The reference behavior: The level of use of DMP in the Mercury School (1974-1980).

those who know the history of DMP in the Mercury School and to assess the model's ability to reproduce the reference behavior shown in Figure 1.

Final feedback and refinement of the model. The last portion of the data collection procedure was to report our progress to the principal and teachers and once again to solicit feedback from them on the assumptions which comprised the theoretical model. A session was held at the school from 4:00 to 5:30 p.m. The principal and most of the teachers were present. Feedback from teachers and principal on the first formulation of the model was sought and given with respect to the accuracy of specific parameters (e.g., initial values of variables, annual changes in transfer rates, and district-wide test results). Feedback data obtained during this session became the basis for refining both the reference behavior graph and the model.

The Setting

Several criteria guided the choice of the system dynamics site. We wanted the school to be small and conveniently located with a willing administration and faculty. Since we were interested in studying a school which had undergone the full cycle of implementation--from adoption to discontinuation--we needed a site which had recently decided to discontinue a particular innovative curriculum. After considering all 13 research sites, one of the urban sites which met all the above criteria was selected.

The school, which we call Mercury School, was opened as an IGE school in September 1974. The decision to be an IGE school was made by a central office-appointed Building Committee composed of administrators, teachers, and parents who lived in the neighborhood. (A complete description of the adoption of IGE at Mercury School may be found in Technical Report 529, Barrows, Klenke, & Heffernan, 1979).

In keeping with district policy, the principal of the school, Dorothy Foster, was appointed 6 months prior to the opening of the school. Mrs. Foster played a major, but not fully determining role in selecting the initial faculty. Due to declining enrollments in other parts of the city, several teachers had been placed on an "excess" list. Teachers on this list as well as teachers with seniority had to receive serious consideration in the hiring of the Mercury staff. Yet, staff members believed that more than just seniority was involved in hiring. As one original staff member still teaching in the school expressed:

> . . ..people were selected by seniority necessarily. You cannot have a staff of 24-year-old kids, but then you can't have a staff of 50-year-old dinosaurs either; you have to have a cross-section and I think that this school was staffed with some vets and some "newees" (Barrows, Klenke, & Heffernan, 1979, p. 7).

Following a 40-hour inservice in August 1974, Mercury School opened with a student population of 307. The school population remained stable for 2 years. The transfer rate between September 1974 and June 1976 stood at about 2%. The city school district underwent racial desegregation in September 1976, at which time the school population rose to a high of 540 during the 1976-1977 school year. The transfer rate during that school year rose to 50%. During the next 2 school years, the student population was stable at 457 and the transfer rate fell to 30% per year. The 1979-1980 student population stands at 380; the current transfer rate is 12% per year.

The Innovation

The curriculum of Mercury School is innovative in a number of major respects. It is an IGE school with a unit organization. Instruction is strongly individualized. The Wisconsin Design for Reading Skill Development is the basis for the district-wide reading program.

The particular innovation which became the focus for this study is called Developing Mathematical Processes (DMP). DMP was introduced by the principal to the primary grades at the opening of the school and to the upper grades 3 years later (1977-1978). The faculty voted in May 1979 to discontinue DMP in favor of a textbook series which, according to teacher reports, lends itself to individualized instruction. DMP emphasizes understanding mathematical processes (in contrast to the traditional focus on developing specific computational skills) and induction (in contrast to the traditional use of didactic methods, verbal explanations, and word problems, children frequently use manipulatives). A detailed description of DMP may be found in Appendix A.

Our intent has been to study the changing level of DMP use in the school from 1974 to 1980. Level of use was defined as the proportion of mathematics instruction in the school based exclusively upon the use of the materials and approaches of DMP. This level of use has been defined as diminished either by the use of supplementary materials to teach specific computational skills didactically or by the replacement of DMP with a different program of instruction. Thus, when the faculty voted to replace DMP with the textbook program, the level of use of DMP came to reflect only the use of DMP materials as supplementary (i.e., a low level of use).

In the next chapter, the use of DMP at Mercury School from 1974 to 1980 will be discussed in narrative and graphic form.

CHAPTER III

RESULTS

The use of Developing Mathematical Processes (DMP) began when Mercury School opened in 1974. From fall 1974 through spring 1977, its use was limited to the primary grades, but in the fall of 1977 the innovation spread to the upper grades. In the spring of 1979 a staff decision was made to discontinue use of DMP.

Originally, the research staff assumed that when DMP was fully implemented in the primary grades (K-2) for 3 years, but not implemented in the upper grades (3-6), the average level of use was 33% (or less, depending on how often primary teachers used supplementary materials).

At a feedback session, the research staff discovered it was inappropriate to combine grades 3 and 4 with the upper grades, analytically. In a sense grades 3 and 4 had become the battleground between those who believed that DMP was good for young children (teachers in K, 1, and 2) and those who espoused the need for direct teaching or specific computational skills (teachers in grades 5 and 6).[1]

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[1]The model could be reformulated to accommodate a "tri-partite" division of Mercury School into primary (K-2), intermediate (3-4), and upper (5-6) grades. Reformulation of the model would allow not only a more accurate representation of the historical reality of the school, but it would also make clearer the "battleground" concept which emerged in our last session with the principal and teachers. It would be useful to explore further the generation of conflict over DMP in the school and to represent the role of conflict structurally in the model. Due to the R & D Center decision to discontinue the Studies of Implementation research, such a reformulation was not possible.

Teachers in grades K to 2 were relatively protected from the pressures exerted on the upper grade teachers to prepare students for the district-wide achievement tests (which are administered in that district to fifth grade students).

This knowledge about the distribution of values and pressures led to a tentative formulation of the model. As a result of this finding, the model was constructed to display the relative isolation of the K through 2 teachers in contrast to the substantial pressures felt by teachers in grades 3 through 6. These pressures were generated by problems resulting from differences between mathematics teaching at the Mercury School (DMP) compared to the rest of the school district (non-DMP). These problems were most intensely felt in dealing with transfer students (transfer rates in 1976-1977 and 1977-1978 were 50% in each year) and in confronting the markedly low standardized achievement test scores associated with DMP. A sophisticated analysis was done of the 1978 achievement test results. The teachers reported that differences in reading and math test scores were as great as 50% (sixth grade in reading vs. third grade in math). In addition, the longer students received instruction in DMP, the lower were their scores on the district-wide standardized achievement tests.

The identification of the changing level of use of DMP at Mercury School and the recognition of several important factors affecting that level of use--the pressure of district-wide achievement tests, differences in primary and upper grade teachers' perceptions of appropriate learning strategies for children, and the transfer rate--resulted in the generation of a dynamic hypothesis and a systems dynamics model. In the following sections of this chapter, the dynamic hypothesis and model are presented as well as some tests of the effect of the various factors.

The Dynamic Hypothesis

A broad hypothesis about the dynamics of curriculum change in the school emerged from our interview data. This hypothesis is formulated below with specific reference to DMP:

> The level of use of DMP in the Mercury School is a function of cross pressures generated over time by discrepancies between the salient characteristics of the innovation and the value priorities of individuals and groups in the school district.

Major system elements include primary and upper grade teachers and students, the principal, parents, and other people or agencies in the city-wide school district. Some discrepancies affect the curriculum more than others and the curriculum responds by seeking equilibrium at a level which balances out the cross pressures.

The effects on the curriculum of school district norms and practices are mediated by standardized test scores and by the teachers' need to deal with students coming from other schools. For example, the higher the transfer rate, the greater the impact of discrepancies between the Mercury School's curriculum and that of other schools in the district.

It is also assumed that there are significant developmental differences between primary and intermediate grade students, differences which can be affected by instruction, but which to some extent are developmental.

Broadly speaking, the theory put forth in the dynamic hypothesis characterizes the curriculum decision-making system in the form of a thermostat model. In this kind of model, the critical value (e.g., of heat in one's home) responds to pressures generated by a discrepancy with a desired value (i.e., the thermostat setting). In the Mercury School model, there are multiple settings which influence decisions about curriculum. One of these settings, a powerful one, is external to the school itself. This "thermostat" setting is found in the norms and practices of the school district as a whole. School district norms are manifested in materials and methods of teaching in the majority of its schools, in the values and expectations of the central administration, and significantly, in the values which characterize the standardized tests to which teachers, administrators, and students are held accountable. School district norms and practices are unaffected by the norms and practices of any single school in the district.

Whereas school district norms and practices are assumed to be exogenous, the other factors comprising the model respond reciprocally to pressures from one another. Thus, primary and intermediate teachers influence one another. Both influence and are influenced by the principal and parents. Teachers and students influence each other and influence and are influenced by the current state of the curriculum.

Policy decisions constitute responses at particular moments in time which are generated by cross pressures produced by these multiple "thermostat settings." Although the effects of such decisions may be diluted by subsequent counter pressures, their influence at certain points in time can be powerful. Even though the vote on a particular policy decision may be close, for example, its effects can be dramatic, at least in the short run, because this policy decision controls both expectations and resources. Also, it carries the weight of binding authority. Such policy decisions operate much like switches, dichotomous rather than continuous in their effects. In this way, small differences are magnified by policy decisions which carry the school one way or another at a particular point in time.

Model Behavior

A continuous simulation model was formulated about curriculum change at the Mercury School, based on the interview data and refined by the interactive process of data collection. Major assumptions which have been built into the computer model include the following:

1. Both school policy and teacher judgments affect changes in school curriculum.

2. Teachers are able to affect curriculum policy directly by the manner in which they use the curriculum and indirectly by their influence on the principal.

3. Teacher judgments about curriculum policy are influenced by many factors:

a. the principal as persuader;

b. the principal as resource provider;

c. the judgments of fellow teachers and, to a lesser extent, parents;

d. teacher perceptions about what is best for the age level of their students;

e. extra workload (real and perceived);

f. differences between the school and city-wide curriculum, as reflected in test scores and in the difficulty of placing transfer students and adapting them to the school's curriculum.

4. Test scores and transfer students have a differential effect on the perceptions of teachers in the primary and upper grades.[2]

Model Outputs

The base run. Basic confidence in the model is related to the credibility of the assumptions upon which it is founded and upon

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[2]The full set of equations which comprise the Mercury School model is included in an appendix to this paper. The reader may wish to compare the verbal descriptions of the assumptions upon which the model is founded with the model equations through which those assumptions are incorporated in the model program.

the model's ability to reproduce accurately the reference behavior which it is seeking to explain. The purpose of the base run is to evaluate how accurately the model reproduces the reference behavior. The reference behavior represents empirical behavior in the real world. The reader will want to compare the average level of use of DMP from 1974 to 1980 which the model produces (Figure 2) with the actual average level of use according to the teachers and principal during that period of time (Figure 1). Note that the model output is consistent with the staff's perceptions about average level of use and in the distinction between the primary and intermediate grade levels of use.

The base run is not a normal run typical of continuous simulation models. As indicated earlier, one of the interesting issues that this research raised was the impact, at least in the short run, of dichotomous policy decisions. A reasonable argument can be made that when consideration is given to a longer time frame (e.g., 25 to 50 years), the apparently dramatic effects of these "policy switches" is smoothed out over the long curve. Thus, it was interesting to compare a "normal" run (i.e., one without policy switches) with the base run, which incorporates the impact of several policy decisions, including the vote of the faculty, in 1979, to formally discontinue DMP after 5 years (60 months in the model) of use. In addition, the policy switch in the model was "thrown" internally, based upon a decision that if the average desired DMP was less than 50% it was reasonable to assume that DMP would be voted down. It is,

TIME	PTDDMP	ITDDMP	ADDPMS[3]
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.656	49.383	62.607
8.	88.105	49.959	62.675
12.	87.182	51.866	63.638
16.	86.313	54.377	65.022
20.	85.472	56.819	66.370
24.	84.583	58.872	67.442
28.	83.641	60.470	68.194
32.	82.708	61.708	68.708
36.	81.821	62.655	69.044
40.	80.985	62.288	68.520
44.	80.182	57.981	65.381
48.	79.441	47.324	58.030
52.	78.813	34.876	49.522
56.	78.306	27.714	44.578
60.	77.924	23.328	41.527
64.	77.631	21.016	39.888
68.	77.557	22.585	40.909
72.	77.655	29.674	45.668

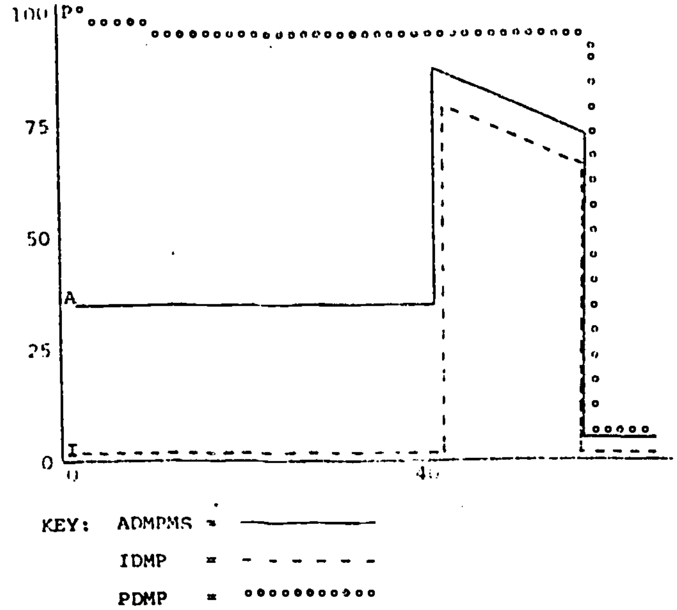


Figure 2. Base run. Average (ADMPMS), primary (PDMP), and intermediate (IDMP) grade levels use of DMP in the Mercury School, 1974-1980 (Scales indicate 0 - 100% level of use.)

Note. Each of the remaining figures displays a table and a graph. The reader should note that the variables printed in the table are not the same as those which are plotting in the graph. Plotted in the graph are the levels of DMP in the Mercury School over time. What the reader sees are the percent of DMP in the primary and intermediate grades throughout the model run. Also displayed is the average percent of DMP under the same conditions during the same time period. The reader will recall that the primary grades are K through 2 and that the intermediate grades are 3 through 6. Thus, in calculating the average DMP, the intermediate grade value is weighted twice. The computer will, on occasion, print multiple symbols to the top right of a line of the graph. For example, in Figure 2, "AIP" is shown to the top right of the last three dots. Such markings simply indicate where more than one variable falls at the same point on the graph. In this case, for example, the computer is informing the reader that the "A" on the graph actually stands for "A," "I," and "P" simultaneously.

in fact, "voted down" in the model just as it was in the Mercury School.

In what we are calling the normal run, several aspects of structure become different from the base run. First of all, the upper grades (called "intermediate grades" in the model) are not prevented from using DMP if they wish, even before the 3-year waiting period (which was a policy decision by the principal in the real situation). Second, neither they nor the primary teachers are pushed by policy to implement DMP. Furthermore, the intermediate grade teachers are able to experience DMP from the beginning and, therefore, to be affected by this experience.

In this run, both primary and intermediate teachers are assumed to start from nonuse of DMP. By way of contrast, in the base run, the primary grade teachers are presumed to start at full use of DMP, as the result of an initial policy decision by the principal. The "normal" run is shown in Figure 3. It can be seen that in the "continuous mode" as well as in the "policy mode" DMP is clearly favored more by primary grade teachers than by intermediate grade teachers. However, even among the primary grade teachers, discontinuation occurs after experience with the innovation over time. This is still assuming a principal who is strongly in favor of the process-oriented curriculum.

Tests of Effects

One purpose of expressing theory in the form of a continuous simulation model is that the model can be used to test the sensi-

TIME	PTI	ITDDMP	ADDPMS
e+00		e+00	e+00
.0	90.[illegible]	50.000	63.333
4.	89.097	48.274	61.881
8.	88.355	45.628	59.870
12.	87.628	[illegible]1.450	56.843
16.	86.827	[illegible].801	53.475
20.	85.945	31.752	49.816
24.	84.951	25.397	45.248
28.	83.843	18.707	40.419
32.	82.688	14.083	36.951
36.	81.523	11.213	34.650
40.	80.360	9.332	33.008
44.	79.229	7.957	31.714
48.	78.203	6.922	30.683
52.	77.262	6.156	29.858
56.	76.425	5.752	29.310
60.	75.722	5.791	29.101
64.	75.126	6.299	29.242
68.	74.594	7.233	29.687
72.	74.091	8.460	30.337

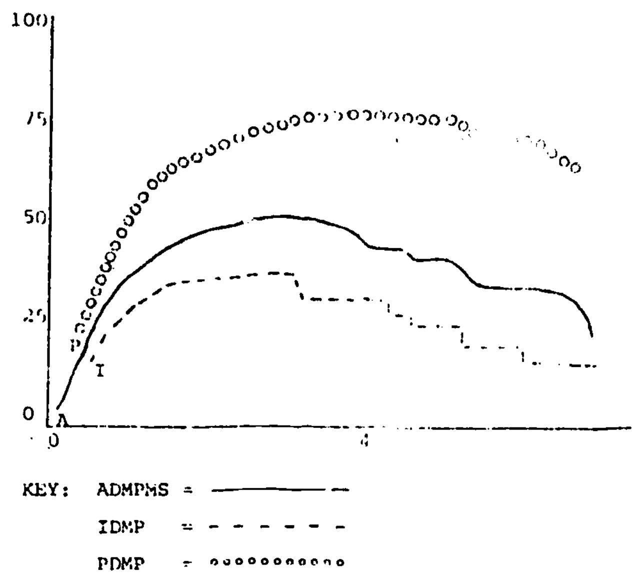


Figure 3. The "normal" run--without the effects of dichotomous policy decisions.

tivity of the situation to an individual and the joint effects of specific variables. A large number of tests of effects have been performed with the model, more than would be profitable to reproduce here. However, several examples are shown, both to illustrate the procedure and to suggest some possible implications.

The effects of the principal. In the real Mercury School, the principal was a strong advocate of DMP. She chose it as the math curriculum in the primary grades at the time the school was first opened and the intermediate grade teachers have reported that she was influential in persuading them to accept it in 1977. Although clearly not all-powerful, a principal commands influence and leverage in a school. Together with her own leadership skills, this principal had positional authority, which was respected by the teachers, and control over resources, including, not insignificantly, control over fiscal resources for curriculum materials. The interviews, both in the Mercury and Jupiter schools, make clear the impact that the withdrawal of even a few hundred dollars per year can have on the ability of teachers to continue implementing a nondistrict-wide innovation, even one in which they have a vital interest.

Thus, it is useful to examine the effect of the principal on the course of the innovation, given the assumptions built into the model. We intend to compare this run (Figure 4), in which the effects of the principal are neutralized, with the base run (Figure 2).

Clearly, withdrawing the effects of the dual influence of the principal on the school changes the pattern of innovation sig-

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.098	48.339	61.925
8.	88.381	46.612	60.535
12.	87.752	44.294	58.780
16.	87.103	41.325	56.584
20.	86.345	37.458	53.754
24.	85.423	31.793	49.670
28.	84.365	24.775	44.638
32.	83.250	18.990	40.410
36.	82.121	15.365	37.617
40.	80.993	13.052	35.699
44.	79.869	11.451	34.257
48.	78.816	10.295	33.135
52.	77.860	9.450	32.254
56.	77.014	9.019	31.684
60.	76.299	9.131	31.520
64.	75.687	9.777	31.747
68.	75.136	10.786	32.236
72.	74.617	11.865	32.782

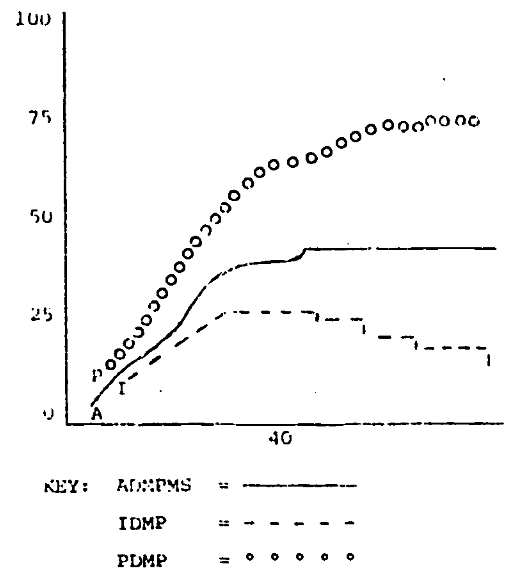


Figure 4. Model behavior without the effects of the school principal.

nificantly. Not surprisingly, when the effects on the curriculum of the principal are withdrawn, the results bear a striking resemblance to the "normal" run (see Figure 3). This, of course, is because the principal is the carrier of policy in the school, as well as a direct influence on teachers. Therefore, when the effects of the principal are removed, there are no binding policies with respect to curriculum. Rather, teachers are free to respond on their own to the pressures which operate in the environment. The reader will remember that the absence of binding policy was the defined condition in the "normal" run.

Given the assumptions of the model, at least three other variables might be powerful enough to alter significantly the pattern of the innovation over time. These are student fit, the transfer rate, and the test scores on the standardized mathematics test.

There is solid empirical evidence, reported consistently in the course of the interviews, supporting the notion that test scores paved the way for the formal discontinuation of DMP in the Mercury School. One teacher reported the following:

> I think the main thing [that led to the decline in support for DMP] was when we got our math scores back from our city-wide testing. They were published in the paper. Other teachers from other schools talked to me about it. (Interview 1, 11/9/79)

Another teacher identified pressure from parents because of the students' performance on the standardized tests:

> You're dealing with people [teachers] on the front line with parents everyday and then we have to justify the low test scores because whatever standardized test we're giving they don't make an exception because we haven't zeroed in on a lot of computational skills. And so these folks being on the front line there have to have the kinds of material that they feel will do the job and not get them off the hook but let parents understand that they are really adding, subtracting, multiplying, and dividing and that kind of thing. (Interview 2, 11/9/79)

On the basis of the interview data, several trends emerged. First, the test scores of the Mercury students were low, not only in comparison to the math scores of students in other schools, but also in comparison to the students' own reading scores. Second, the longer students were exposed to DMP, the worse were their scores on the district-wide test. Third, the results of the test scores were influential with many teachers, especially the upper grade teachers. It was apparently also true of the third and fourth grade teachers, who told us that they felt great pressure because of the test.

Another critical variable, at least one that was mentioned in almost every interview, is the transfer rate. In the words of the teachers:

> The students coming in at all grade levels found it difficult to work into DMP and the teachers found it difficult to bring them into it because they had worked in math series that were very different and so bringing them in, I think, posed a problem. (Interview 2, 11/9/79)

> It's a program [DMP] that I don't think lends well to a high mobility of children. . .with DMP it's the kind of a program that children start out in kindergarten. They learn responsibilities, travelling around, working with partners, and they develop it. But because of the mobility of the kids--we get kids coming in at all grade levels and then they would leave our school half way through the first grade and then they would go to a different school that had an entirely different program and, of course, they were not prepared for it which I think we have to take into consideration now in adopting programs. (Interview 3, 1/9/79)

Transfer rate is an exogenous variable, not influenced by events or policies within the school. It has the effect in the model of multiplying the effects of discrepancies between the school's and the school district's curricular norms and practices. When the school's curriculum, as was the case in mathematics with DMP, is significantly different from the vast majority of other schools in the city, students transferring from other schools do not fit very well with the curriculum. Specifically, teachers in the Mercury School reported with great frequency problems in placing transfer students accurately in groups. The reason teachers gave was that transfer students tended to be comparatively advanced in their computation skills, but comparatively behind in their understanding of mathematical processes. Teachers in the Mercury School also reported that they often had to spend a great deal of time reteaching transfer students, especially with respect to the differences in orientation and terminology. Primarily because of city-wide racial desegregation, the transfer rate to the Mercury School rose dramatically for 3 years, from 1976 to 1979.

Finally, it seemed clear from the interview data that a critical variable for teachers in making curriculum decisions is the perceived fit of the curriculum with the developmental learning mode of their students (Wadsworth, 1979). One of the key points of difference between primary teachers and those teaching older students was in their perceptions of how they learned best. Teachers of young children seem much more comfortable with the use of manipulatives. Teachers of older children put much more emphasis on didactic methods and verbal approaches. Direct statements from the teachers during the interviews illustrate the different points of view of the primary and upper grade teachers.

> My viewpoint would be this,
> In the primary grades. . .numbers, everything is new to the child. And it is just so nice to have something concrete for them to handle or manipulate and I think that was a definite plus for DMP. (Primary teacher, Interview 1, 1/9/79)
>
> I guess too at the upper level once they do not have that real, strong background in computation or facts, once you move into three-digit and four-digit multiplication and

> division, it just seems overwhelming for them and for the teacher to try and figure out why they can't understand the concepts but then when you look at that then they don't understand all the facts that they should already know. . .you find you're having to go back and work on facts. . .I guess that would be one of the reasons too why there was not a lot of support for DMP [in the upper grades]. (Upper grade teacher, Interview 1, 1/9/79)

As indicated earlier, the base run, which is the logical point of reference for assessing the test results, is not a normal run for a continuous simulation model. Continuous simulation models are most useful in analyzing the effects of policy interventions on the problem system's patterns of response. The primary concern of continuous simulation is to understand the dynamics of these response patterns. It is not to make what are commonly called "point predictions."

For example, in this study of mathematics curriculum change in the Mercury School, we are trying to understand the nature of the counter pressures to which the curriculum responds. The curriculum is powerfully influenced by school district norms and practices. The pressures from these norms and practices are strongly mediated by standardized tests and by the impact on teachers of students transferring from other schools in the district. It would be helpful to be able to predict precise values at particular points in time. Clearly, this would demonstrate what most would likely consider "perfect theory." However, what is critically important for the assessment of policy alternatives is to understand the interaction of proposed policies with other variables in the problem system and to be able to predict the kinds of effects (i.e., the trends) which may derive from different policy choices.

The trends which the model describes, trends which appear to be highly consistent with the history of DMP in the Mercury School, are quite stable. They are generally insensitive to parameter changes. However, to fit the timing of the actual policy decisions followed in the Mercury School situation, it is necessary that the specific value of the averaged desired DMP (ADDPMS) be less than 50% at month 60 (i.e., at the end of the fifth year). There is no way to "fix" this result unless the basic trends are consistent with its occurrence. Depending upon the value of the normal fractional rates of increase and decrease, the point at which the value of average desired DMP falls below the "magic policy decision point" may vary by a year or so one way or the other. Thus, in interpreting the test results, it seems important for the reader to know precisely how the fractional rate parameters were set. The only fact that was not possible to establish with certainty by referencing the interview tapes and rechecking with teachers was the exact vote which led to the formal discontinuation of DMP in the Mercury School. There is unanimous agreement about the result of the vote but unresolvable lack of clarity about whether it was close or one-sided.

The best estimate we have been able to attain is that there was a 60-40 split among the faculty against DMP. With this in mind, the fractional rates were set at a value (=.005) which allowed the average desired DMP to fall approximately 40% (precisely 41.527) at the time the vote was taken. Again, as indicated above, this was possible only because the basic trend was one of a falling ADDPMS. The trend derives from the internal structure of the model, not from "playing with parameters."

This approach has set up a point of comparison. Having placed the base run at the known value at the time of the vote, it now becomes possible to compare the value of the average desired DMP at the same point under different test conditions. The results are illuminating. (Note: Once established, the normal fractional rates are constant throughout the analysis. They do not change from one run to another.)

What emerges is clearly a two-fold phenomenon. First, we see a stable pattern of outcomes which appears to be substantially robust with respect to the effects of single, or even multiple variables. Second, individual or combinations of variables appear to impact upon the system primarily by changing the slopes of its response patterns. The result is that the main trends remain highly resistant to change. At the same time, the trends are shifted, sometimes substantially, so that the value of the average desired DMP at the time of the 1979 vote can be quite different under different test conditions. The implication seems to be that DMP might have lasted longer in the Mercury School under certain conditions than under others. An experiment was done to test this idea. The model was run under a combination of highly favorable assumptions for a long period of time (30 years). The assumptions were (a) no standardized tests, (b) no transfer students, and (c) a very high (100%) fit between DMP and the developmental learning characteristics of students. Even over this long period of time, two patterns stood out, patterns which were also evident in the shorter (6 years) run. The first was that there was a very slow, but continuing decline in average desired DMP. The other was that, at the end of the run, support for DMP was still high (72.7%).

In the following figures, the reader is presented with graphical output from the computer model which provides information about the results of the tests described above. In examining all of the test runs, the reader will want to compare the results with the base run. To the extent that a particular test run is different from the base run, it can be inferred that the test variable has a singular effect upon the behavior of the model.

Effects of Test Scores

Figure 5 shows the behavior of the model without the effects of the test scores upon the teachers. The pattern thus far has been to examine the effects of these variables sequentially, to take them in order and to examine their effects singly and then in combination. In Figur . . we look at the effects of the variable, student fit with DMP, in combination with testing and transferring before examining its singular effects (Figure 7).

This shift in the established sequence raises an interesting point. The effects of student fit in combination with test scores and transfer rate contrast sharply with its singular effects. The result of this contrast is to illustrate a common finding in studying complex systems. This finding has become almost an adage among some systems analysts: "What is better in the short run may be

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.079	49.299	62.559
8.	88.263	49.219	62.234
12.	87.534	49.850	62.411
16.	86.857	50.925	62.902
20.	86.188	52.174	63.512
24.	85.450	53.410	64.090
28.	84.635	54.535	64.568
32.	83.801	55.516	64.944
36.	82.982	56.351	65.228
40.	82.191	56.591	65.124
44.	81.431	56.429	64.763
48.	80.706	54.549	63.268
52.	80.020	50.557	60.378
56.	79.438	46.723	57.628
60.	79.015	44.604	56.074
64.	78.711	43.825	55.454
68.	78.468	43.755	55.326
72.	78.247	43.912	55.357

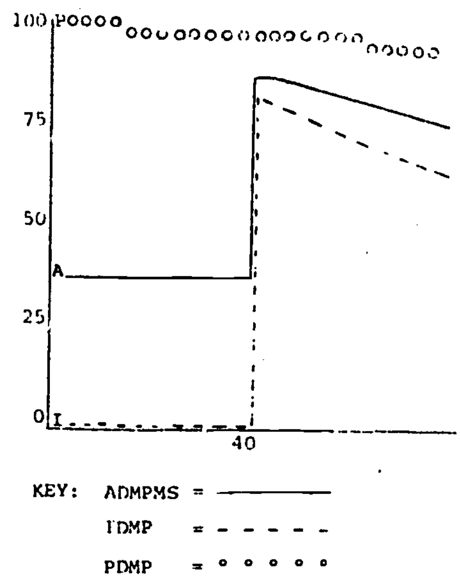
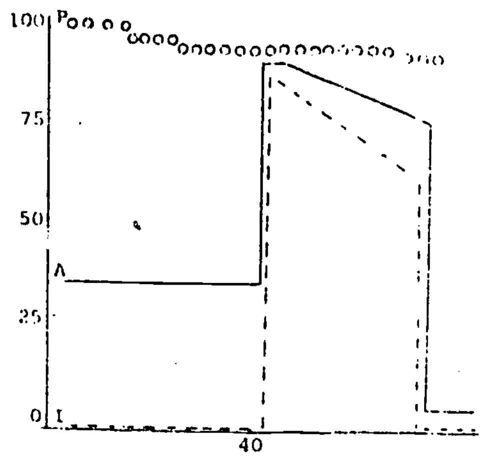


Figure 5. Test run removing the impact of test scores on teachers.

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.056	49.383	62.607
8.	88.109	49.959	62.676
12.	87.190	51.866	63.640
16.	86.327	54.377	64.027
20.	85.510	56.819	66.383
24.	84.730	58.872	67.491
28.	83.979	60.470	68.306
32.	83.256	61.707	68.890
36.	82.562	62.654	69.290
40.	81.893	62.081	68.685
44.	81.229	57.771	65.590
48.	80.590	50.613	60.602
52.	79.958	44.400	56.253
56.	79.395	40.284	53.321
60.	78.901	37.803	51.502
64.	76.457	36.662	50.194
68.	78.054	34.729	49.171
72.	77.833	36.413	50.220



KEY: ADMPMS = ————

IDMP = - - - - - -

PDMP = o o o o o

Figure 6. Test run removing the impact of the transfer rate on teachers.

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.079	49.299	62.559
8.	88.267	49.219	62.235
12.	87.542	49.850	62.414
16.	86.870	50.925	62.907
20.	86.224	52.174	63.524
24.	85.587	53.410	64.136
28.	84.953	54.535	64.674
32.	84.319	55.516	65.117
36.	83.685	56.351	65.463
40.	83.056	56.473	65.334
44.	82.434	56.262	64.986
48.	81.829	55.387	64.201
52.	81.245	54.368	63.327
56.	80.687	53.549	62.595
60.	80.160	53.006	62.057
64.	79.678	52.733	61.715
68.	79.267	52.621	61.503
72.	78.918	52.598	61.371

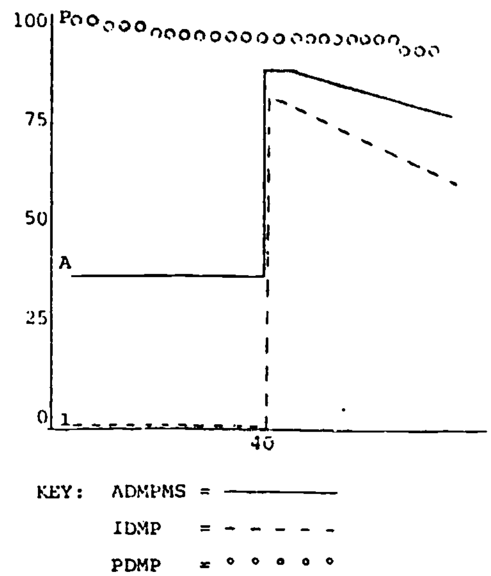


Figure 7. Test run removing the combined effects of test scores and the transfer rate on teachers.

worse in the longer run."

In Figure 8, three assumptions are combined which produce positive results with respect to support for DMP. In this test run, the behavior of the system is observed assuming that (a) there are no standardized test results to contend with, (b) there are no transfer students to be dealt with, and (c) student fit with DMP, both primary and intermediate, is assumed to be perfect.

The combined effects of the three variables on the behavior of the model are substantially greater than the singular effects of either the transfer rate or the test scores. They are also substantially greater than the combined effects of just the transfer rate and the test scores. The following table illustrates the differences in effect upon the average desired DMP in the Mercury School (ADDPMS). In each case the value of ADDPMS shown is the value at month 60 (i.e., at the time of the vote).

Test variable	Value of ADDPMS at the time of the vote
Base run	41.527
Transfer rate only	51.502
Test scores only	56.074
Transfer rate and test scores	62.057
Transfer rate, test scores, student fit	78.031

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.079	54.726	66.177
8.	88.267	60.313	69.631
12.	87.546	67.128	73.934
16.	86.885	73.713	78.104
20.	86.273	78.052	80.793
24.	85.726	80.708	82.380
28.	85.255	82.447	83.383
32.	84.857	83.567	83.997
36.	84.522	84.230	84.327
40.	84.237	84.381	84.333
44.	83.993	83.632	83.752
48.	83.781	81.678	82.379
52.	83.591	79.137	80.622
56.	83.412	76.998	79.136
60.	83.234	75.430	78.031
64.	83.051	74.326	77.235
68.	82.862	73.563	76.663
72.	82.667	73.051	76.256

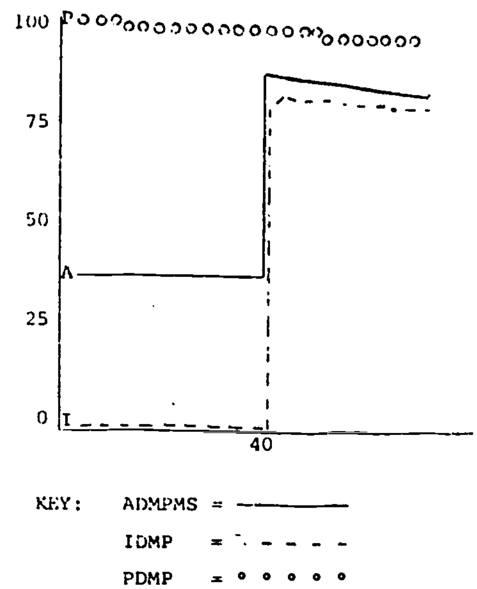


Figure 8. Test run showing the combined impact of test scores, transfer rate, and high student fit with DMP.

It may be tempting to conclude that the effects of student fit are the most important effects. Data provided in Figure 9, however, temper this conclusion.

The reader will notice that, in this run (Figure 9), the impact of student fit is quite different than we found it to be earlier. In combination with no standardized tests and no transfer students, high student fit added considerably to the short- and long-term value of average desired DMP. By itself, this is not at all the case. The value of ADDPMS in this run is no higher than in the base run (in fact, it is a shade lower). Two general systems concepts account for this unexpected result. One was mentioned earlier: "Better can sometimes lead to worse." The other concept is that the essence of systems behavior lies in the interactions among variables. What happens in this case is common. The effects of transferring and testing are delayed, partly because that is the reality (i.e., the physics of the situation) and partly, in this particular case, because the intermediate teachers did not actually experience DMP in their own classrooms for 3 years. (This was the principal's policy which was easy to implement since there was no overwhelming enthusiasm for DMP among intermediate teachers, anyway.) Thus, the effect of the high student fit, real and perceived, is to raise the level of DMP (and the desired level of DMP) to substantially higher values 2 and 3 years into the run. The longer term result is that when "reality rears its ugly head" (in the form of poor test scores and difficulties with transfer students, especially in the upper grades), the fall is greater than under conditions where the early "high" was

TIME	PTDDMP	ITDDMP	ADDPMS
e+00	e+00	e+00	e+00
.0	90.000	50.000	63.333
4.	89.056	55.295	66.549
8.	88.106	64.637	72.460
12.	87.186	75.742	79.557
16.	86.340	81.897	83.378
20.	85.580	85.501	85.528
24.	84.861	87.553	86.656
28.	84.178	88.575	87.109
32.	83.583	88.920	87.141
36.	83.089	88.814	86.906
40.	82.680	87.789	86.086
44.	82.318	81.298	81.638
48.	81.989	67.815	72.540
52.	81.670	46.390	58.150
56.	81.346	28.322	45.997
60.	81.022	20.735	40.831
64.	80.687	17.797	39.760
68.	80.488	19.003	39.498
72.	80.416	25.566	43.849

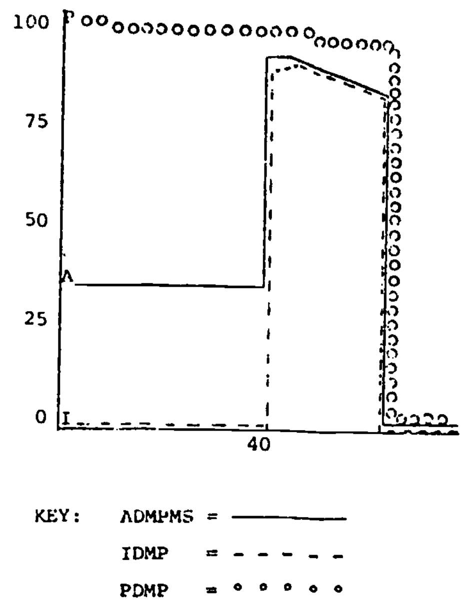


Figure 9. Test run showing the effects of high fit with DMP.

not attainable. In more technical language, the reader will observe that the rate of decline is sharper in this run than in the base run. (Notice, particularly, the differences in ADDPMS between the base run, Figure 2, and that displayed in Figure 9.)

In this chapter, the dynamic hypothesis was presented in addition to the model output and behavior. Tests of the effects of several factors were included. Specifically, the effects of perceived student fit with curriculum, test scores, transfer rate, and principal support were examined. In the next chapter, the implications of these tests of effects will be shared.

CHAPTER IV

IMPLICATIONS

General Implications

Normally, the objective of system dynamics simulation is policy analysis. A problem is defined, in the generic manner, as a discrepancy between an observed state of affairs and a more desired one. Policy questions are perceived to be logically or historically relevant to the problem. Finally, boundary setting (i.e., the choice of the model variables) is guided by the nature of the problem and by the policy questions to be addressed. Model outcomes are directed toward evaluating courses of action and making policy recommendations in terms of assessed effects upon the "problem system."

In this case, our effort has taken primarily a research orientation. What defines the relevance of our continuing efforts to understand the context of organizational stability and change is the history of research and conceptualization about planned change. As suggested earlier in the paper, the dominant theme of research on innovation has been on the characteristics of innovators and on the barriers to and tasks of adoption and implementation. The historical perspectives have been on persons in the early days of study and on management in more recent writings and investigations.

The thrust of the work reported in this paper has been empirical, but not in the usual sense. Rather, it is a continuing effort to engage "subjects" as colleagues in a joint search for knowledge of the cross pressures which are the fabric of organizational stability and change. We have not pretended that the data are "hard."

We have assumed, quite reasonably we believe, that there is a great deal of useful knowledge which is neither quantified nor written. In addition, there is a rich store of important information which is hard won by experience in schools and other organizations. Through an interative and interactive process of data collection, we have tapped the experience of those in one elementary school who lived the "mini-life cycle" of one innovation.

Findings and implications will be fuller as more case studies using this method of reserach are undertaken. However, there are a few tentative conclusions to be drawn from the present work.

Specific Implications

Several policy implications have emerged from this study, although their presentation is tempered by the knowledge that drawing conclusions from them for practice is not simple. On the other hand, they suggest ways of thinking about the context of innovation which transcend simple management strategies.

A set of assumptions was derived from the interview data upon which the model was constructed. Evidence in these data supported the importance of the principal's role in determining the success or failure of an innovation. Clearly, the principal is an important influential in the school. The principal also embodies authority and is the key agent through whom policy decisions are formalized. The principal controls resources without which, the data suggest, it can be difficult or impossible to proceed with a piece of curriculum.

However, the principal is not an all-powerful figure. Strong forces operate in and around the school which seriously affect the ability, and desire, of the principal and teachers to continue with an innovation. It is only when strategies are available to alter or neutralize constraining elements that significant long-term change becomes feasible.

For example, in this analysis, three elements were identified as critical in the failure of DMP to sustain itself at Mercury School for more than a few years. These included the actual and perceived fit of the innovation with the developmental learning characteristics of the students and the relationship between the school's curriculum and that of the rest of the school district. Carriers of the school district norms and practices in the situation studied were the standardized tests and the effects of transfer students on the teachers who had to deal with them.

The interaction among these elements stands as a useful example of the importance of attending not only to the specific values of the variables over time but to the dynamics which produce those values. The discussion asserted the position that something which is demonstrably "good" may turn out, in conjunction with other existing conditions, to have unanticipated "bad" effects. Who can deny that introducing a curriculum which has a high degree of fit with the students' developmental learning characteristics is "good"? On the other hand, the evident benefits of a particular innovation may not be sufficient to guarantee its success in the long run. What the analysis suggests is that to the extent that the innovation is inconsistent with important norms and practices in the school district, it may, by its very implementation create the pressures that ultimately lead to its discontinuation.

In assessing the implications of this analysis for practice, another difficulty arises. It is one thing, in working with the model, to define a test condition such as "withdrawing the effects of. . . ." This is a simple technical task to perform on the model. A challenging task, however, is to translate the test condition into operational terms in a school. It seems important, then, to give attention to this problem in defining implications for practice.

Let us deal, by way of illustration, with the three variables we have been discussing. What would it mean, in practice, to withdraw the effects of the test scores and transfer rates? Does it make sense to think about a strategy in which students in a special program should not have to take the district-wide tests? Is it practical to assert that they should be permitted to take other tests more consistent with the objectives of that program? This is not to say that such a strategy could not be successfully implemented.

On the other hand, a simpler strategy follows from the analysis. This is to engage students in a special preparation program for a period of time prior to taking the standardized tests. In this way, they may become familiar with the traditional vocabulary of those tests and with their model formats. Thus, the special program may be protected from the deleterious impact of the district-wide testing program by a strategy of "teaching to the test" (which, it can be argued, is perfectly legitimate if what is being taught is not the content of the test, but rather its format).

By the same token, while it may not be feasible to isolate the school from the effects of school district transfer policies, an important strategy to protect the environment of the special program may be to buffer the impact of these transfer students in other ways. For example, incoming transfer students might be required to undergo an intensive orientation program prior to placement in regular classes.

Equally difficult to assess are the practical implications of achieving a "high student fit" with the innovation. For one thing, it is no simple task, given the current state-of-the-art, to identify a curriculum which has such a fit in reality. Another complication lies in the important distinction between actual and perceived fit. The model makes this distinction. Assuming, as may be true in some cases, that the real fit of the innovation to students' learning characteristics is better than some teachers percei[illegible] to be, a so-called "normative-reeducative" strategy of organi[illegible]on development may be in order. It is well known from experience, however, that these strategies can be tenuous. They often fly in the face of beliefs acquired during professional training and even in the teachers' own schooling experiences. Many of these beliefs are reinforced by other teachers within the school, and altering these may, in practice, be no simple task.

It has not been the purpose of this discussion to make substantive policy recommendations. Rather, the intent has been to illustrate the problem and the process of moving from analytic results to practical policy formulations. What seems critical, however, is that the analytic process directs the planner toward issues of relationship and interaction and toward problems as patterns of response.

From a system's perspective, wisdom is a sense of context. The implication is that wisdom lies in longer time frames and in attending more to multiple and reciprocal causes. Ecologists remind us that it is not possible to do only one thing at a time. Whatever policy one pursues in the name of short-term interests will have long-term systemic consequences. Our experience with pesticides and drugs has told us more about this concept than we may have wished to know. At the same time, in the service of singular goals, it is often necessary to adopt complex strategies. Our analysis of the implementation and discontinuation of DMP in the Mercury School certainly seems to support this admonition.

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Appendix A

Developing Mathematical Processes

DEVELOPING MATHEMATICAL PROCESSES

Developing Mathematical Processes (DMP) is a complete program of mathematics instruction designed for use in grades K-6. DMP was developed by the Analysis of Mathematics (AMI) Project of the Wisconsin Research and Development Center for Cognitive Learning, School of Education, University of of Wisconsin-Madison. Funds for its development began in 1967 and continued to its completion in 1976. Funds were received from several sources: US Office of Education, National Institute of Education, National Science Foundation, and the State of Wisconsin. DMP is currently available from the Rand McNally Publishing Company.

Developing Mathematical Processes was developed through a cooperative effort of mathematics educators, child psychologists, mathematicians, and classroom teachers. The initial thrust of the AMI project was to study the relationship between instructional processes, methods and materials and the acquisition of mathematical learning. From this study, it became apparent that new instructional materials were needed. This led to the development of experimental teaching units. From these units the complete elementary (K-6) mathematics program (DMP) evolved.

DMP is suitable for use in the broad spectrum of American classrooms by all teachers for all children with the exception of those who are severely physically, emotionally, or mentally handicapped. Since DMP's availability in 1974, it has been implemented in a wide variety of schools and locations across the country, and in several private schools in other countries. Several areas of DMP implementation deserve special mention: Children of migrant workers; bilingual students, specifically in Texas where the Spanish-language version of DMP is being used, Early Childhood Programs in California; Title I special remedial programs; and several schools under the responsibility of the Bureau of Indian Affairs. It has, however, been found that DMP has not been widely implemented in schools in large urban systems.

DMP has six major objectives:

1. To provide an activity-oriented manipulative-based instructional program that is an innovative alternative to the traditional paper-pencil workbook and textbook programs.

2. To develop a sound conceptual base upon which children can build profiency in and an understanding of arithmetic, geometric, and problem-solving skills.

3. To provide opportunity in development and practice of basic arithmetic skills with whole numbers, fractions, and decimals.

4. To provide children with ample learning activities so that they can become proficient as independent, willing, and creative problem-solvers.

5. To assist teachers better meet the needs of individual students by providing a variety of learning activities, suggestions for different grouping patterns, assessment and record keeping materials, and an adequate supply of interesting and motivating non-print materials.

6. To use all of the above to help create a more positive atmosphere so teaching and learning mathematics is a pleasurable experience.

Three features describe the program. Pedagogically, DMP is a child-oriented program in which children actively investigate and study mathematical aspects of their environment. It is designed as an ungraded, continuous progress program build upon sets of learning objectives. Physical manipulatives, stories, games, and paper-and-pencil activities are provided for student use. Teacher materials include guides for program use, assessment and evaluation tools, and procedures and record-keeping devices.

Psychologically, DMP is an activity program in which children learn to represent their world with mathematical symbolism after learning concepts, relationships, operations, and processes in concrete situations. Student motivation receives primary attention through the use of a variety of instructional activities, multiple classroom organizational and grouping patterns, and a problem-solving approach to learning.

Mathematically, DMP is approached through measurement rather than set theory. Using various processes, describing, classifying, ordering, joining, grouping, and partitioning, children examine objects, sets, and events in their world. Relevant attributes, length, height, weight, areas, numerousness, time, duration, and capacity are the focus of such examination. These processes are used to explore the attributes and their relationship and operations between them. Ultimately, the children symbolically represent the attributes by measuring, and the relationships and operations by writing mathematical sentences. In addition to the arithmetic of the rational numbers, geometry and elementary statistics are a part of the DMP program.

Source. Wisconsin Research and Development Center for Individualized Schooling, Technical Proposal 1978-1979. Madison, Wisconsin, 1978, 746-748.

```
*                    Mercury School Model
*               A.K. Gaynor -- February, 1980
*
*
*                    Curriculum Sector
*
*
*               Primary Grades
*
*
*          Level of DMP in the Primary Grades
*
l pdmp.k=(pdmp.j+dt*(ripdmp.jk-rdpdmp.jk))
n pdmp=pdmpn
c pdmpn=100
*
*   pdmp=primary grade dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   ripdmp=rate of increase in pdmp (units/mo)
*   rdpdmp=rate of decrease in pdmp (units/mo)
*   pdmpn=initial value of pdmp (units)
*
r ripdmp.kl=(((dipdmp.k*easidp.k)/cat)+eppidp.k)
a dipdmp.k=(ptddmp.k-pdmp.k)*sw1.k
a sw1.k=clip(1,0,ptddmp.k,pdmp.k)
a easidp.k=table(teasidp,prddmp.k*evote2.k,0,100,25)
t teasidp=0,.2,1,1.5,2
c cat=36
a eppidp.k=step(ppht.k,pptime)*evote2.k
a ppht.k=fepol*(100-pdmp.k)
c pptime=0
c fepol=.25
a evote2.k=clip(0,1,swv2.k,1)
a swv2.k=x.k*y.k
a x.k=clip(1,0,time.k,vtime2)
a y.k=clip(0,1,addpms.k,ravote)
c vtime2=60
c ravote=50
*
*   ripdmp=rate of increase in pdmp (units/mo)
*   dipdmp=desired increase in pdmp (units)
*   easidp=effect of administrative support on increases in dmp
*      (dimensionless)
*   cat=curriculum adjustment time (months)
*   eppidp=effect of primary grade policy on increases in pdmp (dimensionl
*   evote2=effect of vote 2 (dimensionless)
*   ptddmp=primary grade teachers desired dmp (units)
*   pdmp=primary grade dmp (units)
*   sw1=switch 1 (dimensionless)
*   clip=a branching function
*   table(tabhl)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   teasidp=table of easidp values
```

```
*    prddmp=principal's desired dmp (units)
*    step=increase in a rate of a stated height at a stated time
*    ppht=primary policy step height (units/mo)
*    pptime=time of implementation of primary policy (months)
*    fepol=fractional effect of policy (dimensionless)
*    pdmp=primary grade dmp (units)
*    sw=switch (dimensionless)
*    tippti=table of ippti values
*    swv2=switch for vote 2 (dimensionless)
*    x=dummy variable
*    y=dummy variable
*    vtime2=time of vote 2 (months)
*    addpms=average desired dmp in the Mercury School (units)
*    rqvote=required level of desired dmp to retain the program (units)
*
r rdpdmp.kl=(ddpdmp.k/cat)+easddp.k+(pev2pd.k*sw11.k)
a ddpdmp.k=(pdmp.k-ptddmp.k)*sw2.k
a sw2.k=clip(0,1,ptddmp.k,pdmp.k)
a easddp.k=((pdmp.k-prddmp.k)/adt.k)*sw12.k
a adt.k=tabhl(tadt,prddmp.k*evote2.k,0,50,25)
t tadt=1,12,24
a sw12.k=clip(0,1,prddmp.k,pdmp.k)
a pev2pd.k=pdmp.k/polat
c polat=1
*
*    rdpdmp=rate of decrease in pdmp (units/mo)
*    ddpdmp=desired decrease in pdmp (units)
*    cat=curriculum adjustment time (months)
*    easddp=effect of administrative support on decreases in pdmp
*       (dimensionless)
*    pev2pd=policy effect of vote 2 on the rate of decrease in
*       primary dmp (units/mo)
*    sw11=switch 11 (dimensionless)
*    pdmp=primary grade dmp (units)
*    ptddmp=primary grade teachers desired dmp (units)
*    sw2=switch 2 (dimensionless)
*    clip=a branching function
*    prddmp=principal's desired dmp (units)
*    adt=administrative discontinuation time (months)
*    sw12=switch 12 (dimensionless)
*    table(tabhl)=a list of "y" coordinates corresponding to
*       the "x" scale values indicated
*    tadt=table of adt values
*    evote2=effect of vote 2 (dimensionless)
*    polat=policy adjustment time (months)
*
*
*         Primary Teachers Desired Level of DMP
*
l ptddmp.k=ptddmp.j+dt*(iptddp.jk-dptddp.jk)
n ptddmp=ptddpn
c ptddpn=90
*
*    ptddmp=primary grade teachers desired dmp (units)
*    dt=simulation time interval of computation (fraction/mo)
*    iptddp=rate of increase in primary teachers desired dmp (units/mo)
*    dptddp=rate of decrease in primary teachers desired dmp(units/mo)
*    ptddpn=initial value of ptddmp (units)
```

```
*
r iptddp.kl=nfiddp*(100-ptddmp.k)*eprpti.k*eitpti.k*eppti.k*epsfdi.k
x *etfdip.k*etspti.k*(1/pewddp.k)
c nfiddp=.005
a eprpti.k=delay3(iprpti.k,12)
n iprpti=1
a iprpti.k=tabhl(tiprpti,prddmp.k-ptddmp.k,-20,20,10)
t tiprpti=.5,.67,1,1.5,2
a eitpti.k=delay3(iitpti.k,12)
n iitpti=1
a iitpti.k=tabhl(tiitpti,itddmp.k-ptddmp.k,-20,20,10)
t tiitpti=.85,.95,1,1.1,1.15
a eppti.k=delay3(ippti.k,12)
n ippti=1
a ippti.k=tabhl(tippti,ppddmp.k-ptddmp.k,-20,20,10)
t tippti=.85,.95,1,1.05,1.15
a epsfdi.k=tabhl(tepsfdi,ppsfdp.k-ptddmp.k,-30,30,10)
t tepsfdi=.2,.4,.67,1,1.5,2.5,5
a etfdip.k=delay3(itfdip.k,6)
n itfdip=1
a itfdip.k=eptddn.k*pestr.k
a eptddn.k=tabhl(teptddn,sddmp.k-pdmp.k,-30,30,10)
t teptddn=.85,.95,.98,1,1.05,1.1,1.15
a sddmp.k=tabhl(tsddmp,time.k,0,60,12)
t tsddmp=0,0,0,0,0,0
a pestr.k=pestr1.k+pestr2.k
a pestr1.k=tabhl(tpestr1,str.k,0,30,10)*sw9.k
t tpestr1=1,1.05,1.08,1.15
a pestr2.k=tabhl(tpestr2,str.k,0,30,10)*sw10.k
t tpestr2=1,.98,.95,.85
a sw9.k=clip(1,0,sddmp.k-pdmp.k,0)
a sw10.k=clip(0,1,sddmp.k-pdmp.k,0)
a str.k=tabhl(tstr,time.k,0,60,12)
t tstr=2,2,50,30,30,12
a etspti.k=delay3(itspti.k,6)
n itspti=1
a itspti.k=tabhl(titspti,test.k,.5,1,.5)
t titspti=.9,1.1
a test.k=tabhl(ttest,dsdnp.k,-40,40,40)
t ttest=.5,1,.5
a dsdnp.k=admpms.k-sddmp.k
a admpms.k=(pdmp.k+2*idmp.k)/3
a pewddp.k=owldmp*peddpw.k*ess.k
c owldmp=1.5
a peddpw.k=tabhl(tpeddpw,ptddmp.k,0,100,25)
t tpeddpw=2,1.5,1,.75,.67
a ess.k=1
*
*   iptddp=rate of increase in primary teachers desired dmp (units/mo)
*   nfiddp=normal fractional rate of increase in itddmp (fraction/mo)
*   ptddmp=primary grade teachers desired dmp (units)
*   eprpti=effectof the principal on iptddp (dimensionless)
*   eitpti=effect of intermediate teachers on iptddp (dimensionless)
*   eppti=effect of parents on iptddp (dimensionless)
*   epsfdi=effect of perceived primary student fit with dmp on iptddp
*       (dimensionless)
*   etfdip=effect of perceived transfer student fit with dmp on iptddp
*   itfdip=indicated value of etfdip (dimensionless)
```

```
* - etspti=effect of standardized test scores on iptddp (dimensionless)
*   pewddp=effect of perceived dmp workload on iptddp (dimensionless)
*   delay3=third-order exponential delay of the length shown in (   )
*   iprpti=indicated value of eprpti (dimensionless)
*   tiprpti=table of iprpti values
*   table(tabhl)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   prddmp=principal's desired dmp (units)
*   iitpti=indicated value of eitpti (dimensionless)
*   tiitpti=table of iitpti values
*   itddmp=intermediate teachers desired dmp (units)
*   ippti=indicated value of eppti (dimensionless)
*   tippti=table of ippti values
*   ppddmp=primary parents desired dmp (units)
*   tepsfdi=table of epsfdi values
*   ppsfdp=perceived primary students fit with dmp (units)
*   eptddn=effect on primary transfer students of discrepancy with
*      school district norms & practices (dimensionless)
*   pestr=effect on primary grade teachers of the student transfer rate
*      (dimensionless)
*   teptddn=table of iptddn values
*   sddmp=school district level of dmp (units)
*   pdmp=primary grade dmp (units)
*   tsddmp=table of sddmp values
*   time=number of months in the model run (months)
*   pestr1=effect when sddmp>pdmp (dimensionless)
*   pestr2=effect when pdmp>sddmp (dimensionless)
*   tpestr1=table of pestr1 values
*   tpestr2=table of pestr2 values
*   str=student transfer rate (%/yr)
*   sw9=switch 9 (dimensionless)
*   sw10=switch 10 (dimensionless)
*   clip=a branching function
*   tstr=table of str values
*   itspti=indicated value of etspti (dimensionless)
*   test=test scores (fraction of expected test scores)
*   ttest=table of test values
*   dsdnp=discrepancy between school & district levels of dmp (units)
*   admpms=average dmp in Mercury School (units)
*   idmp=intermediate grade dmp (units)
*   owldmp=objective workload from dmp (dimensionless ratio)
*   peddpw=primary grade effect of desired dmp on perceived workload
*      (dimensionless)
*   ess=effect of special support on the effects of workload (dimensionless)
*   tpeddpw=table of peddpw values
*
r dptddp.kl=nfdddp*ptddmp.k*eprptd.k*eitptd.k*epptd.k*epsfdd.k
x *etfddp.k*etsptd.k*pewddp.k
c nfdddp=.005
a eprptd.k=1/eprpti.k
a eitptd.k=1/eitpti.k
a epptd.k=1/eppti.k
a epsfdd.k=1/epsfdi.k
a etfddp.k=1/etfdip.k
a etsptd.k=delay3(itsptd.k,6)
n itsptd=1
a itsptd.k=tabhl(titsptd,test.k,.5,1,.5)
t titsptd=1.1,.9
```

```
*
*   dptddp=rate of decrease in primary teachers desired dmp(units/mo)
*   nfdddp=normal fractional decrease in  desired dmp
*      (fraction/mo)
*   ptddmp=primary grade teachers desired dmp (units)
*   eprptd=effect of the principal on dptddp (dimensionless)
*   eitptd=effect of intermediate teachers on dptddp (dimensionless)
*   epptd=effect of parents on dptddp (dimensionless)
*   epsfdd=effect of perceived primary student fit with dmp on dptddp
*      (dimensionless)
*   etfddp=effect of transfer students on dptddp (dimensionless)
*   etsptd=effect of test scores on dptddp (dimensionless)
*   itsptd=indicated value of etsptd
*   pewddp=effect of perceived dmp workload on iptddp (dimensionless)
*   eprpti=effectof the principal on iptddp (dimensionless)
*   eitpti=effect of intermediate teachers on iptddp (dimensionless)
*   eppti=effect of parents on iptddp (dimensionless)
*   epsfdi=effect of perceived primary student fit with dmp on iptddp
*      (dimensionless)
*   etfdip=effect of perceived transfer student fit with dmp on iptddp
*      (dimensionless)
*   table(tabhl)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   tetsptd=table of etsptd values
*   test=test scores (fraction of expected test scores)
*
*
*              Intermediate Grades
*
*
*         Level of DMP in the Intermediate Grades
*
l idmp.k=idmp.j+dt*(riidmp.jk-rdidmp.jk)
n idmp=idmpn
c idmpn=0
*
*   idmp=intermediate grade dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   riidmp=rate of increase in idmp (units/mp)
*   rdidmp=rate of decrease in idmp (units/mo)
*   idmpn=initial value of idmp (units)
*
r riidmp.kl=(((diidmp.k*easidi.k)/cat)+evote1.k)*vsw1.k
a diidmp.k=(itddmp.k-idmp.k)*sw3.k
a sw3.k=clip(1,0,itddmp.k,idmp.k)
a easidi.k=easidp.k
a evote1.k=step(iht.k,sttm.k)*vsw2.k
a iht.k=(90-(nriidp.k+idmp.k))*sw5.k
a sw5.k=clip(0,1,time.k,vtime1+6)
a nriidp.k=(diidmp.k*easidi.k)/cat
a sttm.k=vtime1
c vtime1=36
a vsw1.k=clip(1,0,time.k,vtime1)
a vsw2.k=clip(1,0,itddmp.k,nagree)*clip(1,0,time.k,vtime1-1)
c nagree=45
*
*   riidmp=rate of increase in idmp (units/mo)
*   diidmp=desired increase in idmp (units)
```

```
*   easidi=effect of administrative support on riidmp (dimensionless)
*   cat=curriculum adjustment time (months)
*   evote1=effects of vote 1(units/mo)
*   vsw1=vote switch 1 (dimensionless)
*   itddmp=intermediate teachers desired dmp (units)
*   idmp=intermediate grade dmp (units)
*   sw3=switch 3 (dimensionless)
*   clip=a branching function
*   easidp=effect of administrative support on increases in dmp
*      (dimensionless)
*   step=increase in a rate of a stated height at a stated time
*   iht=height of intermediate step (units/mo)
*   sttm=time of intermediate step (months)
*   vsw2=vote switch 2 (dimensionless)
*   ditddp=rate of decrease in itddmp (units/mo)
*   sw5=switch 5 (dimensionless)
*   time=number of months in the model run (months)
*   vtime1=time of vote 1 (months)
*   table(tabh1)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   nagree=needed level of intermediate teachers desired dmp to support
*      initial implementation in the intermediate grades (units)
*
r rdidmp.kl=(ddidmp.k/cat)+easddi.k+(pev2id.k*sw11.k)
a pev2id.k=idmp.k/polat
a sw11.k=clip(0,1,evote2.k,1)
a ddidmp.k=(idmp.k-itddmp.k)*sw4.k
a sw4.k=clip(0,1,itddmp.k,idmp.k)
a easddi.k=((idmp.k-prddmp.k)/adt.k)*sw13.k
a sw13.k=clip(0,1,prddmp.k,idmp.k)
*
*   rdidmp=rate of decrease in idmp (units/mo)
*   ddidmp=desired increase in idmp (units)
*   cat=curriculum adjustment time (months)
*   pev2id=policy effect of vote 2 on the rate of decrease in
*      intermediate dmp (units/mo)
*   idmp=intermediate grade dmp (units)
*   polat=policy adjustment time (months)
*   sw11=switch 11 (dimensionless)
*   clip=a branching function
*   evote2=effect of vote 2 (dimensionless)
*   itddmp=intermediate teachers desired dmp (units)
*   sw4=switch 4 (dimensionless)
*   easddi=effect of administrative support on rdidmp (dimensionless)
*   prddmp=principal's desired dmp (units)
*   adt=administrative discontinuation time (months)
*   sw13=switch 13 (dimensionless)
*
*
*        Intermediate Teachers Desired Level of DMP
*
l itddmp.k=itddmp.j+dt*(iitddp.jk-ditddp.jk)
n itddmp=itddpn
c itddpn=50
*
*   itddmp=intermediate teachers desired dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   iitddp=rate of increase in itddmp (units/mo)
```

```
*   ditddp=rate of decrease in itddmp (units/mo)
*   itddpn=initial value of itddmp (units)
*
r iitddp.kl=nfiddp*(100-itddmp.k)*epriti.k*eptiti.k*epiti.k*eisfdi.k
x *etfdii.k*etsiti.k*(1/iewddp.k)
a epriti.k=delay3(ipriti.k,12)
n ipriti=1
a ipriti.k=tabhl(tipriti,prddmp.k-itddmp.k,-20,20,10)
t tipriti=.5,.67,1,1.5,2
a eptiti.k=delay3(iptiti.k,12)
n iptiti=1
a iptiti.k=tabhl(tiptiti,ptddmp.k-itddmp.k,-20,20,10)
t tiptiti=.5,.67,1,1.5,2
a epiti.k=delay3(ipiti.k,12)
n ipiti=1
a ipiti.k=tabhl(tipiti,ipddmp.k-itddmp.k,-20,20,10)
t tipiti=.75,.85,1,1.18,1.3
a eisfdi.k=tabhl(teisfdi,isfdmp.k-itddmp.k,-30,30,10)
t teisfdi=.2,.4,.67,1,1.5,2.5,5
a etfdii.k=delay3(itfdii.k,6)
n itfdii=1
a itfdii.k=eitddn.k*iestr.k*eietrs.k
a eietrs.k=clip(1,ileits.k,time.k,vtime1)
a ileits.k=1/(eitddn.k*iestr.k)
a eitddn.k=tabhl(teitddn,sddmp.k-idmp.k,-30,30,10)
t teitddn=.2,.4,.67,1,1.5,2.5,5
a iestr.k=iestr1.k+iestr2.k
a iestr1.k=tabhl(tiestr1,str.k,0,30,10)*sw7.k
t tiestr1=1,1.5,2.5,5
a iestr2.k=tabhl(tiestr2,str.k,0,30,10)*sw8.k
t tiestr2=1,.67,.4,.2
a sw7.k=clip(1,0,sddmp.k-idmp.k,0)
a sw8.k=clip(0,1,sddmp.k-idmp.k,0)
a etsiti.k=delay3(itsiti.k,6)
n itsiti=1
a itsiti.k=tabhl(titsiti,test.k,.5,1,.5)*eiewti.k
t titsiti=.1,1.1
a eiewti.k=clip(1,iiewti.k,time.k,vtime1)
a iiewti.k=tabhl(tiiewti,test.k,.5,1,.5)
t tiiewti=10,.9
a iewddp.k=owldmp*ieddpw.k*ess.k*eiewld.k
a ieddpw.k=tabhl(tiewddp,itddmp.k,0,100,25)
t tiewddp=2,1.5,1,.75,.67
a eiewld.k=clip(1,z.k,time.k,vtime1)
a z.k=1/(owldmp*ieddpw.k*ess.k)
*
*   iitddp=rate of increase in itddmp (units/mo)
*   nfiddp=normal fractional rate of increase in itddmp (fraction/mo)
*   epriti=effect of the principal on iitddp (dimensionless)
*   eptiti=effect of primary teachers on iitddp (dimensionless)
*   epiti=effect of parents on iitddp (dimensionless)
*   eisfdi=effect of perceived student fit with dmp on iitddp (dimensionles
*   etfdii=effect of transfer students fit with dmp on iitddp (dimensionles
*   itfdii=indicated value of etfdii
*   etsiti=effect of test scores on iitddp (dimensionless)
*   iewddp=effect of perceived workload on iitddp (dimensionless)
*   delay3=third-order exponential delay of the length shown in (   )
*   ipriti=indicated value of epriti (dimensionless)
```

```
*   table(tabhl)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   tipriti=table of iptiti values
*   prddmp=principal's desired dmp (units)
*   itddmp=intermediate teachers desired dmp (units)
*   iptiti=indicated value of eptiti (dimensionless)
*   tiptiti=table of iptiti values
*   ptddmp=primary grade teachers desired dmp (units)
*   ipiti=indicated value of epiti (dimensionless)
*   tipiti=table of ipiti values
*   ipddmp=intermediate parents desired dmp (units)
*   teisfdi=table of eisfdi values
*   isfdmp=intermediate students fit with dmp (units)
*   eitddn=effect on intermediate transfer students of discrepancy
*      (dimensionless)
*   iestr=effect on intermediate teachers of the transfer rate
*      (dimensionless)
*   eietrs=effect of intermediate experience with transfer students
*         (dimensionless)
*   clip=a branching function
*   ileits=indicated value of eietrs (dimensionless)
*   time=number of months in the model run (months)
*   vtime1=time of vote 1 (months)
*   teitddn=table of eitddn values
*   sddmp=school district level of dmp (units)
*   idmp=intermediate grade dmp (units)
*   iestr1=effect when sddmp>idmp (dimensionless)
*   iestr2=effect when idmp>sddmp (dimensionless)
*   tiestr1=table of iestr1 values
*   str=student transfer rate (%/yr)
*   tiestr2=table of iestr2 values
*   sw7=switch 7 (dimensionless)
*   sw8=switch 8 (dimensionless)
*   itsiti=indicated value of etsiti (dimensionless)
*   titsiti=table of itsiti values
*   test=test scores (fraction of expected test scores)
*   eiewti=effect of intermediate experience with dmp on itsiti (dimensionle
*   iiewti=indicated value of eiewti (dimensionless)
*   time=number of months in the model run (months)
*   tileiti=table of ileiti values
*   ditddp=rate of decrease in itddmp (units/mo)
*   ieddpw=effect of itddmp on perceived dmp workload (dimensionless)
*   ess=effect of special support on the effects of workload (dimensionless)
*   eiewld=effect of intermediate experience with dmp workload (dimensionles
*   tiewddp=table of iewddp values
*   z=dummy variable
*
r ditddp.kl=nfdddp*itddmp.k*epritd.k*eptitd.k*epitd.k*eisfdd.k
x *etfddi.k*etsitd.k*iewddp.k
a epritd.k=1/epriti.k
a eptitd.k=1/eptiti.k
a epitd.k=1/epiti.k
a eisfdd.k=1/eisfdi.k
a etfddi.k=1/etfdii.k
a etsitd.k=delay3(itsitd.k,6)
n itsitd=1
a itsitd.k=tabhl(titsitd,test.k,.8,1,.2)*eiewtd.k
  itsitd=5,.9
```

```
a eiewtd.k=clip(1,iiewtd.k,time.k,vtime1)
a iiewtd.k=tabhl(tiiewtd,test.k,.8,1,.2)
t tiiewtd=.2,1.1
*
*   ditddp=rate of decrease in itddmp (units/mo)
*   nfdddp=normal fractional decrease in  desired dmp
*   itddmp=intermediate teachers desired dmp (units)
*   epritd=effect of the principal on itddmp (dimensionless)
*   eptitd=effect of primary teachers on itddmp (dimensionless)
*   eisfdd=effect of intermediate student fit on itddmp (dimensionless)
*   etfddi=effect of transfer students fit with dmp on itddmp (dimensionless
*   etsitd=effect of standardized test scores on itddmp (dimensionless)
*   iewddp=effect of perceived dmp workload on itddmp (dimensionless)
*   epriti=effect of the principal on iitddp (dimensionless)
*   eptiti=effect of primary teachers on iitddp (dimensionless)
*   epiti=effect of parents on iitddp (dimensionless)
*   eisfdi=effect of perceived student fit with dmp on iitddp (dimensionless
*   etfdii=effect of transfer students fit with dmp on iitddp (dimensionless
*   delay3=third-order exponential delay of the length shown in (   )
*   itsitd=indicated value of etsitd (dimensionless)
*   table(tabhl)=a list of "y" coordinates corresponding to
*      the "x" scale values indicated
*   titsitd=table of itsitd values
*   test=test scores (fraction of expected dmp on itsiti)
*   eiewtd=effect of intermediate experience with dmp on itsitd (dimensionle
*   clip=a branching function
*   iiewtd=indicated value of eiewtd (dimensionless)
*   time=number of months in the model run (months)
*   vtime1=time of vote 1 (months)
*   tiiewtd=table of iiewtd values
*
*                     Student Sector
*
*
*                Primary Students
*
l psfdmp.k=psfdmp.j+dt*cpfft.jk
n psfdmp=psfdpn
c psfdpn=100
*
*   psfdmp=primary students fit with dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   cpfft=change in primary student fit with dmp from teaching
*      (units/mo)
*      changes in student population (units/mo)
*   psfdpn=initial value of psfdmp (units)
*
r cpfft.kl=((pdmp.k-psfdmp.k)/sfat)*psfasw.k
a psfasw.k=clip(1,0,pdmp.k,psfdmp.k)
c sfat=24
*
*   cpfft=change in primary student fit with dmp from teaching
*         (units/mo)
*   pdmp=primary grade dmp (units)
*   psfdmp=primary students fit with dmp (units)
*   sfat=student fit adjustment time (months)
*   psfasw=primary student fit adjustment switch (dimensionless)
```

```
l ppsfdp.k=ppsfdp.j+
n ppsfdp=ppsfdn
c ppsfdn=100
*
*   ppsfdp=perceived primary student fit with dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   cppsf=rate of change in perceived primary student fit (units/mo)
*   ppsfdn=initial value of ppsfdp (units)
r cppsf.kl=((psfdmp.k-ppsfdp.k)/percat)*eoldf.k
c percat=600
a eoldf.k=table(teoldf.k,oldf.k,0,10,10)
t teoldf=1,25
a oldf.k=table(toldf.k,time.k,0,72,12)
t toldf=0,0,0,0,0,0,0
*
*   cppsf=rate of change in perceived primary student fit (units/mo)
*   psfdmp=primary student fit with dmp (units)
*   ppsfdp=perceived primary student fit with dmp (units)
*   percat=perception adjustment time (months)
*   eoldf=effect of opportunities to learn about developmental fit
*        (dimensionless)
*   table (tabhl)=a list of "y" coordinates corresponding to
*        the "x" scale of values indicated
*   teoldf=table of eoldf values
*   oldf=opportunities to learn about developmental fit (units)
*   toldf=table of oldf values
*
*
*              Intermediate Students
*
l isfdmp.k=isfdmp.j+dt*cifft.jk
n isfdmp=isfdpn
c isfdpn=40
*
*   isfdmp=intermediate students fit with dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   cifft=change in intermediate student fit with dmp from teaching
*      (units/mo)
*   isfdpn=initial value of isfdmp (units)
*
r cifft.kl=((idmp.k-isfdmp.k)/sfat)*isfasw.k
a isfasw.k=clip(1,0,idmp.k,isfdmp.k)
*
*
*   cifft=change in intermediate student fit with dmp from teaching
*        (units/mo)
*   idmp=intermediate grade dmp (units)
*   isfdmp=intermediate students fit with dmp (units)
*   sfat=student fit adjustment time (months)
*   isfasw=intermediate student fit adjustment time (months)
*   clip=a branching function
*
l pisfdp.k=pisfdp.j+dt*cpisf.jk
n pisfdp=pisfdn
c pisfdn=40
*
*   pisfdp=perceived intermediate student fit with dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
```

```
*   cpisf=r[illegible] of change in pisfdp (units/mo)
*   pisfdn=initial val[illegible] of [illegible]dp (unit[illegible]
*
r cpisf.kl=((isfdmp.k-pisfdp.k)/percat)*eoldf.k
*
*   cpisf=rate of change in pssfdp (units/mo)
*   isfdmp=intermediate student fit with dmp (units)
*   pisfdp=perceived intermediate student fit with dmp (units)
*   percat=perception adjustment time (months)
*   eoldf=effect of opportunites to learn about developmental fit
*        (dimensionless)
*
*
*                    Principal Sector
*
*
l prddmp.k=prddmp.j+dt*ncprd.jk
n prddmp=prddpn
c prddpn=100
*
*   prddmp=principal's desired dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   ncprd=principal's desired dmp (units)
*   prddpn=initial value of prddmp (units)
*
r ncprd.kl=(addpms.k-prddmp.k)/prat
a addpms.k=(ptddmp.k+2*itddmp.k)/3
c prat=60
*
*   ncprd=principal's desired dmp (units)
*   addpms=average desired dmp in the Mercury School (units)
*   prddmp=principal's desired dmp (units)
*   prat=principal's adjustment time (months)
*   ptddmp=primary grade teachers desired dmp (units)
*   itddmp=intermediate teachers desired dmp (units)
*
*
*                    Parent Sector
*
*
*               Primary Grade Parents Desired DMP
*
l ppddmp.k=ppddmp.j+dt*ncppd.jk
n ppddmp=ppddpn
c ppddpn=50
*
*   ppddmp=primary parents desired dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   ncppd=net change in ppddmp (units/mo)
*   ppddpn=initial value of ppddmp (units)
*
r ncppd.kl=(ptddmp.k-ppddmp.k)/pat
c pat=120
*
*   ncppd=net change in ppddmp (units/mo)
*   ptddmp=primary grade teachers desired dmp (units)
*   ppddmp=primary parents desired dmp (units)
*   pat=parent adjustment time (months)
```

```
*
*
*        Intermediate Grade Parents Desired DMP
*
l ipddmp.k=ipddmp.j+dt*ncipd.jk
n ipddmp=ipddpn
c ipddpn=40
*
*   ipddmp=intermediate parents desired dmp (units)
*   dt=simulation time interval of computation (fraction/mo)
*   ncppd=net change in ppddmp (units/mo)
*   ipddpn=initial value of ipddmp (units)
*
r ncipd.kl=(itddmp.k-ipddmp.k)/pat
*
*   ncppd=net change in ppddmp (units/mo)
*   itddmp=intermediate teachers desired dmp (units)
*   ipddmp=intermediate parents desired dmp (units)
*   pat=parent adjustment time (months)
*
*
*     Simulation Control Statements
*
print ptddmp,itddmp,addpms
plot admpms=a,idmp=i,pdmp=p(0,100)
spec dt=.25,prtper=4,pltper=4
n time=ntime
c ntime=0
c length=72
```

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