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INNOVATIVE METHODS FOR STUDYING INNOVATION IN EDUCATION AND AN ILLUSTRATIVE ANALYSIS OF STRUCTURAL EFFECTS ON INNOVATION DIFFUSION WITHIN SCHOOLS.

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PUB DATE 68

EDRS PRICE MF-$0.25 HC-$1.56 37P.

DESCRIPTORS- *EDUCATIONAL INNOVATION, *DIFFUSION, *RESEARCH METHODOLOGY, FIELD STUDIES, INFORMATION DISSEMINATION, SIMULATION, *STRUCTURAL ANALYSIS, RESEARCH NEEDS, GROUP STRUCTURE, INTERACTION PROCESS ANALYSIS, SOCIOMETRIC TECHNIQUES, HIGH SCHOOLS, SECONDARY SCHOOL TEACHERS, *COMMUNICATION (THOUGHT TRANSFER), SPEECHES, MICHIGAN,

THE PURPOSES OF THIS PAPER ARE TO EXAMINE THE RESEARCH METHODS GENERALLY UTILIZED IN DIFFUSION RESEARCH AND TO SUGGEST RESEARCH METHODS WHICH MIGHT HELP PROVIDE A BETTER UNDERSTANDING OF THE DIFFUSION PROCESS. TO PROMOTE THE UNDERSTANDING OF THE COMPLETE DIFFUSION PROCESS OF EDUCATIONAL CHANGE, RESEARCH SHOULD CONSIDER THE DECISION-MAKING PROCESS, THE PROCESS OF GATEKEEPING, OR THE ROLE OF THE INTERMEDIATE DISSEMINATORS, THE IMPLEMENTATION OF AN INNOVATION AFTER IT HAS BEEN ADOPTED, AND THE EFFECTS OF INNOVATION UPON EDUCATION. RESEARCH METHODS WHICH OFFER PROMISE IN SOLVING SOME OF THE PROBLEMS OF STUDYING EDUCATIONAL CHANGE ARE FIELD EXPERIMENT, COMPUTER SIMULATION, AND STRUCTURAL ANALYSIS, THE RELATIONSHIPS BETWEEN THE VARIOUS PROPERTIES OF GROUP STRUCTURE AND INNOVATION DIFFUSION INDEXES. A STUDY OF INNOVATION DIFFUSION AMONG TEACHERS IN THREE MICHIGAN HIGH SCHOOLS DEMONSTRATED HOW GROUP STRUCTURAL PROPERTIES CAN BE ANALYZED IN A WAY THAT IS MEANINGFUL AND THAT SHEDS LIGHT ON THE DIFFUSION PROCESS. IT DEMONSTRATED THAT THE DIFFUSION PHENOMENA WITHIN ORGANIZATIONS MAY BE EXPLAINED AND PREDICTED FROM CERTAIN STRUCTURAL PROPERTIES. FOR EXAMPLE, THOSE WHO PLAY LIAISON ROLES AND WHO ENJOY HIGH PRESTIGE AMONG FELLOW MEMBERS SHOULD BE STUDIED BECAUSE THEY ARE RELEVANT TO THE INTRODUCTION OF AND RECEPTIVITY TO THE INNOVATION IN THE SOCIAL SYSTEM. STRUCTURAL ANALYSIS HAS POSSIBLE IMPLICATIONS FOR EDUCATIONAL ORGANIZATIONS OR POLICY MAKERS ATTEMPTING TO INNOVATE BECAUSE IT CAN PROVIDE INFORMATION ABOUT THE OPTIMAL PROCESS FOR DISSEMINATING NEW IDEAS AND PRACTICES AND ABOUT THE COMPATIBILITY BETWEEN THE FORMAL AND INFORMAL STRUCTURES WITHIN A SYSTEM, AND IT MAY BE USED TO IMPROVE THE STRUCTURE FOR INNOVATION ASSIMILATION. THIS SPEECH WAS DELIVERED AT THE NATIONAL CONFERENCE ON THE DIFFUSION OF EDUCATIONAL IDEAS (MICHIGAN STATE UNIVERSITY, MARCH 26-28, 1968). (MM)

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*Paper presented at the National Conference on the Diffusion of Educational Ideas, held at Michigan State University, East Lansing, Michigan, March 26-28, 1968
Sponsored by The Research Coordinating Unit of the Vocational Education Division of the Michigan Department of Education In cooperation with The United States Office of Education and The Department of Communication and Continuing Education Service, Michigan State University.

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AN OVERVIEW OF RESEARCH METHODS

The purposes of this paper are (1) to examine the research methods generally utilized in diffusion research, and (2) to suggest certain research methods which may help provide us with better understanding of the diffusion process. Before I attempt to discuss these topics, however a few points of clarification are in order.

Research method, at its best, is a tool used to test our conceptualization of a given problem. Some methods are admittedly better suited than others for testing certain conceptual schemes, but a "good" method paired with a poor conceptual scheme will lead us nowhere. Therefore, throughout this paper, I will try to demonstrate whenever and wherever possible, the relationships between various research methods and research conceptualization.

Research method is very liberally defined here. It includes all phases of research when a strategic decision has to be made in regard to the design, sampling, operationalization of variables, data collection, data processing and analysis. In a broad sense, a research method is the complete operationalization process of a conceptual or theoretical scheme and will be considered as such in this paper.

In order to examine the research methods generally utilized in studying innovation diffusion, it may be fruitful to describe a simplified, somewhat typical example of such a study.

Let us imagine that Researcher A wants to study the diffusion of an educational innovation or a number of innovations in a school system. First of all he designs a conceptual scheme in which the central focus is the extent of innovativeness in the system. Operationally, innovativeness is measured in terms of the time required for the innovation to be adopted, the degree of adoption, or the number of innovations adopted.

The researcher then defines the population he wants to survey, which usually consists of a number of students, teachers or superintendents. Then he determines how to draw a sample from this population. A questionnaire is designed which includes the adoption index as well as a number of social and psychological variable items.

These social and psychological variables are to be taken as the independent variables or factors which may explain the degree of innovativeness of the system. Then, a research team goes to the research locale and interviews all the people included in the sample. The team asks the respondents to give opinions or factual information (through recall). The completed questionnaires are then coded, keypunched on IBM cards, sometimes standardized, and fed into computers. Correlational or multiple-regressional analysis routines are used to determine the extent to which (in variance terminology) each of the independent variables explains the dependent variable - which is the innovativeness of the system. Hopefully some simple inter-correlations will reach the significant level of .05 or the variance explained will exceed 40 or 50 percent.

From this simplified, hypothetical diffusion study, we have isolated some characteristics of the research methods generally employed and I would like now to point out some of these characteristics more specifically and to comment on them.

(1) Our research focus has been very narrow (especially the selection of dependent variables). Inevitably, it is the innovativeness of either an individual or a system. Operationally, the focus is likely to be the extent of adoptions of a number of innovations or the earliness of adoption dates.

(2) Furthermore we usually rely on the respondent's recall ability in obtaining such data. Reliability of such data, especially when data involve recalled dates of first adoptions, becomes rather questionable.

(3) Our unit of analysis is usually the person who adopts or rejects the innovation. In other words, our research attention has been pretty much receiver-oriented.

(4) Our research is usually a one-shot job. We conduct one survey in a given time period, which means we see a slice of reality at a frozen point of the time dimension.

(5) Our analytic schemes consist mainly of correlational analyses. The tendency is such that we try to include as many independent variables as possible and let the computer or graduate students tell us which correlations and how many such correlations are significant. For the more daring scholars, ingenuity is well used to conceptualize a paradigm or theory which hopefully will account for the relationships between the independent and dependent variables.

I have given a sterile and rather critical discussion about the research methods utilized, methods upon which we are trying to build our understanding of the diffusion of educational ideas. To critically evaluate the shortcomings of the research methods, we must now take a step backward and ask ourselves two basic questions.

(1) What do we really want to know about the diffusion of educational ideas and practices?

(2) Are the research strategies currently being employed capable of giving us such information?

The first question is a conceptual one. It seems to me that investigation of the diffusion of educational innovations should be made a concrete vehicle for understanding educational change. An understanding of educational change, in turn, should lead us into building a sounder educational institution, which constitutes one of the backbones of the social system.

If this argument is valid, then we must know not only how and why schools or teachers adopt innovations. We must understand as well the process by which the innovations are diffused or disseminated to the schools and teachers. This further implies that we must take a process view of the problem at issue. Given this conceptualization, we must have a wider scope of research foci and we must see inovativeness within a school system or among teachers not as the end-goal in our research strategy, but as a component in the dynamic process of educational change.

What, then, should we, as researchers, take into consideration once we have determined that an understanding of the complete diffusion process of educational innovations is essential? In other words, to what other components, in this conceptual schema, should we also pay our research attention? I would like to suggest the following considerations.

(1) We must pay more attention to the decision-making process. Decision-making takes place when the initiators of innovations consider alternative new practices and ideas, when the intermediate disseminators (or "gatekeepers") make their choices among innovations legitimized by the initiators and transmit the selected parts, features, or information about the innovations to filter down to the receiving or adopting units, and when the adopting units assess the values and assets of the innovations filtered down to them and decide to what extent they want to adopt or internalize the new ideas and practices. So, decision-making is a very complex process which involves different strata of decision-makers as well as different internal stages. Some of these distinctions are discussed elsewhere and I will not go into detail here.[12]

(2) We must further investigate the process of gatekeeping. As I just mentioned, an innovation is usually diffused through a number of levels in the educational system. The intermediate units in many cases have extensive power in determining to what extent the information about the innovation and the innovation itself will be diffused or disseminated to the adopting units. An understanding of the belief systems and information processing patterns of these gatekeepers is certainly a necessary ingredient in our understanding of educational change.[10]

(3) We must find out how an innovation is implemented after it has been adopted. The process of innovation diffusion does not terminate when the innovation is adopted. How is it actually implemented? To what extent have the adoptors internalized (or become attitudinally committed to) the innovation? Are all available manpower and equipment being effectively utilized? How should presently unavailable but necessary manpower and equipment be made available? All these problems of innovation implementation need research attention.

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(4) Finally, we must study the effects of innovation upon the education system and its relevant societal environment. A change in one part of the structure is likely to cause changes in other parts. And the school system is but a subsystem in the social system. How can we determine the extent of success or failure of an innovation in an educational system? How does the school system assess the effects of an innovation? Again, these questions call for immediate research attention.

In suggesting a process view of the diffusion of education innovation, I have raised a number of relevant questions. Are the research strategies currently employed capable of giving us answere to these questions? The reply is a painful "no". In order to have a clear view of educational change we must widen our research to cover more than just the innovativeness of the adopting units, we must get more reliable data, other than from recall, we must somehow grasp the dimension of time and we must utilize more powerful and precise analytic tools to assess our data.

In the last two decades many new research methods have been developed which may help answer our conceptual questions. In the following section, I would like to discuss three such methods which promise to help solve some of the problems faced by students of educational change. Promising though these methods are, I might add, they have not been "diffused" or "implemented" in diffusion research in education.

FIELD EXPERIMENT, COMPUTER SIMULATION AND STRUCTURAL ANALYSIS

The first research method I want to discuss here is field experiment. Survey research has been criticized for its lack of control over extraneous variables. Therefore, the findings from survey research lacks the precision to determine the causal relationship between the dependent and independent variables, even in the weaker sense of such relationship (namely, the sequence of occurrences of the variables in a bounded segment of time). On the other hand, laboratory experiment has been criticized for its narrow definition of population and for its use of a vacuum environment which does not exist in reality. Field experiment is designated as the solution to the debate between generality of findings and precision of measurement. With a representative sampling of a social system and careful manipulation of and control over one or more independent variables, field experiment may achieve both generality and precision.

How can field experiment be used for studying educational innovations? Let me give an example of such usage. At Hopkins, a number of my colleagues are developing simulation games, such as consumer's game, legislature game, parent and child game, and career game. These games are intended to give students an opportunity to experience in a game situation various roles they will have to play when they enter society. Hopefully, these games will help the students to be prepared to face and to adjust to the complex world they will encounter when they leave school. Some of these games have been tried in schools all over the country. Now, it is being considered that the games be systematically disseminated to various school systems. How should such innovations be introduced? This seems to me to be an interesting question. Should they be introduced directly to individual teachers? Or should they be disseminated to the principal or the superintendent? Is it valid to argue that teachers' participation in deciding whether the simulation games be adopted by the school system can affect the eventual success or failure of the innovations? Furthermore, under what circumstances should the games be played by students on a voluntary basis and under what circumstances and with what anticipated effects should they be mandatory?

The selection of the best strategy for disseminating the simulation games calls for a series of field experiments. The research design of such experiments may follow the following procedure:

(1) Select a number of school systems with similar geographical features, similar numbers of students and teachers, and similar degree of innovativeness (in terms of number and kind of innovations adopted in the schools).

(2) Introduce the simulation games through the superintendent and the principal in some schools, through the principal in some other schools, and directly to the teachers or students in still some other schools.

(3) After a period of time, measure the extent of innovation acceptance and duration of innovation acceptance in the various schools systems.

The same procedure can be followed to test the differential effects of teachers' participation in the innovation decision-making process, parents' participations in the innovation decision-making process, and students' voluntary participation on the acceptance and continuing use of simulation games in schools. Of course, the actual design of the field experiments requires more rigorous procedure than the one I mentioned. My purpose here, however, is to demonstrate utilization of a research method in determining which will be most effective in disseminating an educational innovation.

In summary, field experiment is a combination of sampling procedure used in survey research, of vari ble control and of variable manipulation utilized in experiments. With a careful design and representative sampling, this method can not only isolate some low-level causal relationship between a number of variables, but can also help in policy-planning.

The next research method I would like to discuss is computer simulation. Curiously, although computer simulation is seldom utilized in studying educational change, a large member of education researchers are familiar with the terminology. This is perhaps due to the novelty of the term, simulation; and to the overwhelming impression made by the computer.

Simulation, in its dictionary definition, is pretending or feigning. It is, therefore, an imitation of a system or a process in reality. However, simulation has a slightly different meaning in academic circles. It is defined not as the imitation itself, but, rather, as an attempt to imitate. In this sense, simulation can be defined as a logical, technical or mathematical attempt to imitate a system or a

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process in reality through operationalization of a model. The model consists of a set of components and rules. The components correspond to a collection of variables of either social or theoretical significance. The rules specify the relationships and conditions for change among the components.

Three kinds of simulation can be distinguished:

(1) A simulation may be constructed so that we are only interested in the outcome of a set of events or activities. This "black box" approach of simulation is called "one shot" simulation.

(2) When we are interested in simulating the activities or events of a system at various stages over certain periods of time, then we need a "process" simulation. A process simulation attempts to initiate changes in a social system with a set of realistic components and rules.

(3) When we are interested in both the behavior and outcome of a social system over time, then we use a "complete" simulation. A complete simulation is simply an attempt to imitate both the change and outcome of a set of events in a social system over time. It is, therefore, also the most difficult among the three kinds of simulation.

Simulation is inevitably linked with computers; simply because when we attempt to simulate a complex social system, there are too many components and rules to be handled manually or on paper.

How can computer simulation help our study of innovation diffusion in education? If we take the "process" view of the diffusion problem, computer simulation seems to be the logical tool to use. It has the following advantages:

(1) It gives us a structural view of the educational system. We can build in such components as state educational boards, the superintendents, the principals, the teachers, the students, the parents, or whatever combination of these components is called for in a given educational system. The rules used can involve any specific relationship among the board, the superintendent, the principal, the teachers and the students.

(2) Simulation may imitate the dynamic nature of reality. When we set the simulation model to function over time; in effect, we are attempting to imitate the change of the social system over time. This gives us an understanding of how an educational system actually works.

(3) Since a simulation model can be manipulated easily, we may conduct experiments such as rearrangemets of components and rules. We are thus free from the tremendous cost which would be involved were we to conduct such experiments in reality. The social system is also protected from whatever damage and ill effects which might arise from the rearrangement.

In summary, although computer simulation may still be a few years away from significant contribution to the study of education change, it is important that we start exploring this new research method so we may be assured that significant contribution is forthcoming.

The third research method I would like to discuss here is structural analysis. In my opinion, one of the most important tasks in future diffusion research will be the exploring and locking into place of the relationships between the various properties of group structure [1,15,2,8,9] and diffusion of innovation indices [5,6,11,13,14] in the education system. Therefore, instead of describing structural analysis in general terms, I would like in the remainder of this paper to discuss an exploratory study of group structure and innovation diffusion among teachers in three Michigan high schools.

GROUP STRUCTURE AND INNOVATION DIFFUSION WITHIN SCHOOLS

This study is intended to demonstrate how group structural properties can be analyzed in a way that is meaningful and that sheds light on the diffusion process of an educational innovation. The overall investigation was conducted in three Michigan high schools. These were selected on the basis of their similar geography, their comparable sizes, and on their similar degree of innovativeness, as observed in an early short questionnaire survey which covered some 70 high schools in

Michigan[14]. The innovation investigated was flexible scheduling, selected on the following criteria: (1) the innovation was structural and therefore, once it was adopted, it necessarily involved every teacher in the school; (2) the innovation was adopted by the three schools within two years prior to the time of the research project and therefore the recall data from the teachers was still considered reliable.

In the self-administered questionnaire, a sociometric item asked that each teacher nominate three fellow teachers within the school whose opinions he most frequently sought with regard to problems related to the teaching performance. Each teacher was also asked to recall the date (month) prior to the school's adoption of the innovation when he first became aware of the innovation.

A four-item scale called innovation internalization scale also appeared on the questionnaire. This scale was intended to measure the extent to which the teacher was then attitudinally committed to the innovation.[11]

The questionnaire was completed by 45 of 57 teachers in School 1, by 37 of the 53 teachers in School 2, and by all 37 teachers in School 3. After matching the demographic and professional data in the questionnaires (age, salary level, sex, courses taught, and attained educational level) against each school's roster of teachers, we were able to identify 42 teachers in School 1 (74%), 37 teachers in School 2 (70%), and 30 teachers in School 3 (81%), which constituted our final sample for this particular study. No significant differences on sex, attained educational level or salary distribution were found among the teachers at the three schools. Teachers in School 1 tended to be older than those in the other two schools ($X^2 = 14.6$, with Yate's correction, d.f.=6, p-.05).

Innovation Awareness and Internalization

The findings on the dates of initial awareness of innovation and of internalization are presented in Table 1. The median dates of first awareness of the innovation relative to the adoption date for teachers in Schools 1, 2 and 3 were three

Table 1

INNOVATION AWARENESS AND INTERNALIZATION OF TEACHERS IN THREE MICHIGAN HIGH SCHOOLS

	Innovation Awareness			Innovation Internalization		
School	Median Date#	Skewness	Kurtosis	Mean*	Skewness	Kurtosis
School 1 (N=42)	3 months	0.68	2.50	7.56	1.02	2.74
School 2 (N=37)	3 months	4.99	27.81	9.08	0.47	2.36
School 3 (N=30)	4 months	2.83	12.95	6.78	1.36	4.75

Number of months prior to the School's adoption of the innovation. The dates ranged 06-01 months in School 1, 85-01 months in School 2, and 37-01 in School 3. One teacher in School 2 claimed he had not heard about the innovation up to the time of the adoption of the innovation in the school.

* A t-test between Schools 2 and 3 mean scores for all respondents was significant at .01 level (t=3.16, d.f.=72, Var (School 2) = 13.18, Var (School 3) = 6.71).

Table 2

FREQUENCY AND DIRECTION OF (TEACHING ADVICE) COMMUNICATION PATTERNS RELATIVE TO INNOVATION AWARENESS

	Direction of Communication		
School	Upward Communication	Horizontal Communication	Downward Communication
School 1 (N=61)	52.5%	16.4%	31.2%
School 2 (N=41)	34.1	39.0	26.8
School 3 (N=68)	54.4	8.8	36.8

months, three months and four months respectively. School 3 teachers seemed to have become aware of the innovation slightly but not significantly earlier than those in the other two schools. However, the variability of the awareness dates was significant among the three schools. The earliest knower in School 2 reported the date as having been 85 months prior to the school's adoption of the innovation while the earliest knower in School 3 indicated the date as 37 months prior to the adoption. The wide variability of initial awareness among School 2 teachers was indexed by the degree of skewness (lack of symmetry) and kurtosis (relative peakness) of the distribution, also shown in Table 1.

To test whether the differences in the variability of awareness dates in the three schools were indeed due to differences in communication patterns, the awareness data were combined with the sociometric data in the following manner. An incidence matrix constituting all teachers in the sample in each school was constructed, with each row designating a nominating (advice seeking) teacher and each column a nominated (advice-sought) teacher. If teacher A nominated teacher B, then the cell AB (A row and B column) recorded a value of one; otherwise it had a value of zero. The teachers were so ordered in the matrix that the earliest knower occupied the first row and column in the matrix while the latest knower occupied the last row and column. The matrix was further partitioned into groups of teachers who became aware of the innovation during the same month. The resulting three matrices are presented in Appendix A. In each matrix, three types of communication patterns can be observed.

The <u>upward communication</u> was defined as a teacher's nomination of another teacher who had become aware of the innovation earlier than himself. Thus, all the cells in the left lower portion of the matrix, excluding the diagonal cells, were of upward communication. Similarly, <u>downward communication</u> was defined as one teacher's nomination of another teacher who had become aware of the innovation later than he had himself. Therefore downward communication includes the cells on the right upper portion of the matrix. Horizontal communication consisted of the diagonal cells. Tabulations of the actual nominations in these patterns are shown in Table 2.

The data uncovered an important fact: there was more vertical communication (upward and downward communication) among School 3 teachers than there was in School 1, which, in turn, had more vertical communication among its teachers than existed in School 2. In fact, we can see that the proportion of horizontal communication among teachers in School 2 was more than twice that of School 1 and more than four times that of School 3. It seemed that the variability of awareness dates reported by School 2 teachers was indeed related to the communication pattern, namely to the relative lack of communication between early knowers and late knowers.

The four-item internalization scale consisted of two positive and two negative statements, with each item having seven response categories: (1) "agree very much", (2) "agree on the whole", (3) "agree a little", (4) "don't know", (5) "disagree a little", (6) "disagree on the whole", and (7) "disagree very much."

After all data were transformed into the positive direction, the scale allowed a maximum score of 4 (agreed very much on all four items) to a minimum score of 28 (disagreed very much on all four items). As shown in Table 1, the mean scores for Schools 1, 2 and 3 were 7.56, 9.08 and 6.78 respectively. Teachers in School 3 not only showed the most frequent communication between early and later knowers, but also showed the most favorable attitude toward the innovation, relative to those in the two other schools. A t-test indicated that the difference between the mean scores obtained between Schools 2 and 3 was significant (no indication of strong skewness or kurtosis was observed in the distribution of internalization scores for the three schools).

DIFFERENTIAL GROUP STRUCTURAL PROPERTIES

Isolates, Cliques, Opinion Leaders and Liaisons.

I have shown that (1) variability of teachers' awareness dates was related to the communication pattern, and (2) there was a significant difference in the extent of innovation internalization among teachers, with the teachers of Schools 2 and 3 differing the most and with School 1 data falling somewhere in between. It seemed, then, that the extent of teachers' innovativeness, as measured with the first awareness dates and internalization scale scores, indexed School 3 as high, School 1 as moderate, and School 2 as low. Now, let us turn to the advice-seeking network among teachers in order to determine whether any structural clues can be found consistent with the different degrees of innovation receptivity in the three schools.

Presented in Figure 1 are the sociograms of teaching-advice seeking patterns among the teachers for the three schools. A visual check of these sociograms would indicate that the networks in the three schools were of three different types. School 3 structure was tightly connected in a <u>wired-wheel</u> pattern in which each teacher was connected with other teachers in at least one path. We will ignore the direction of the path for the moment.

School 1, with a number of "isolates" (teachers 35, 49 and 21) and with three small cliques (teachers 18-55-56, 42-05-52, and 25-12), presented a <u>satellite</u> structure, consisting of a large group and t satellite groups in its main clique. School 2 had, in addition to a sizable number of isolates, a <u>star</u> structure in the main clique, with a circle-like network and a number of independent lines stretching out along the circle. Such intuitive examination of the communication networks suggested then that three very different group (teaching advice communication) structures existed in the three schools. To put these impressions to rigorous tests, the following indices were constructed:

<u>Number of isolates</u>: An isolate was defined as the teacher who neither nominated nor was nominated by any other teacher sampled in the school. There were no

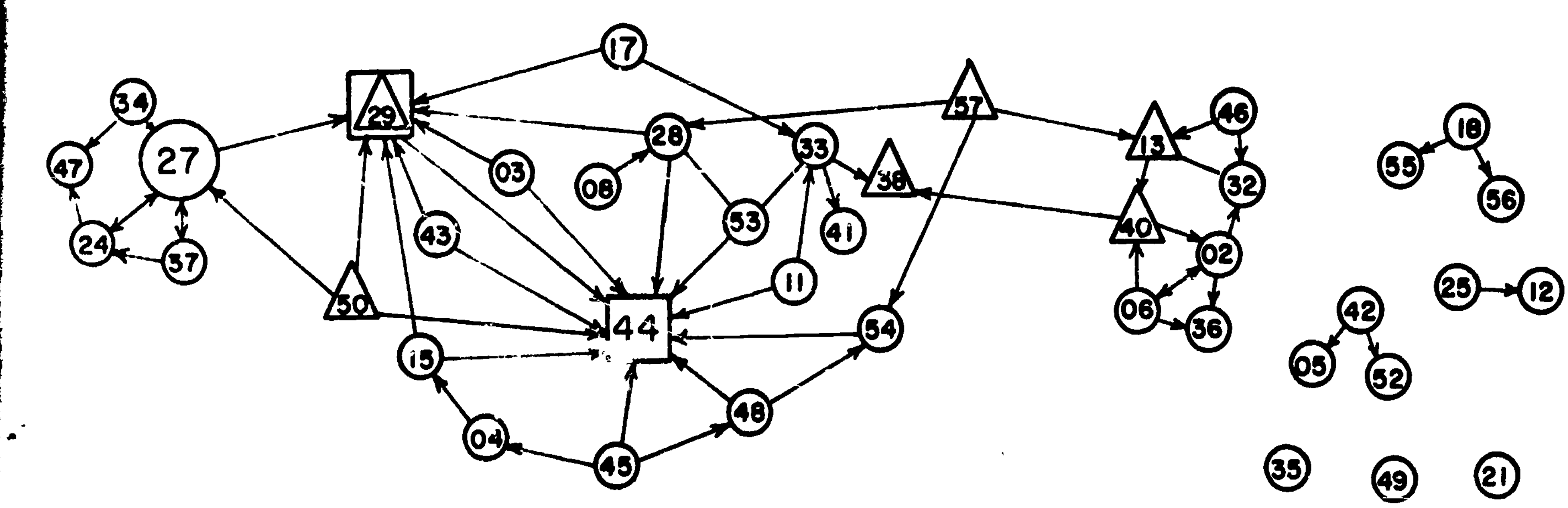

FIGURE 1-A: SCHOOL 1 (N=42)

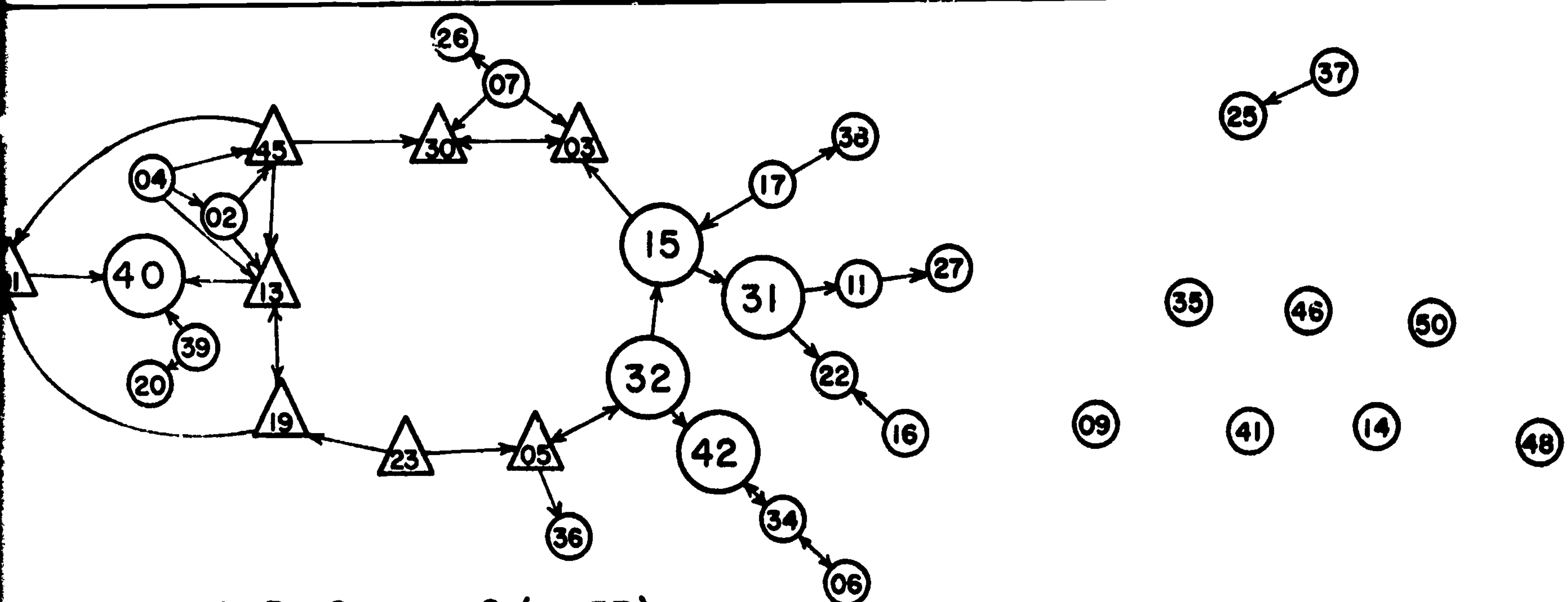

FIGURE 1-B: SCHOOL 2 (N=37)

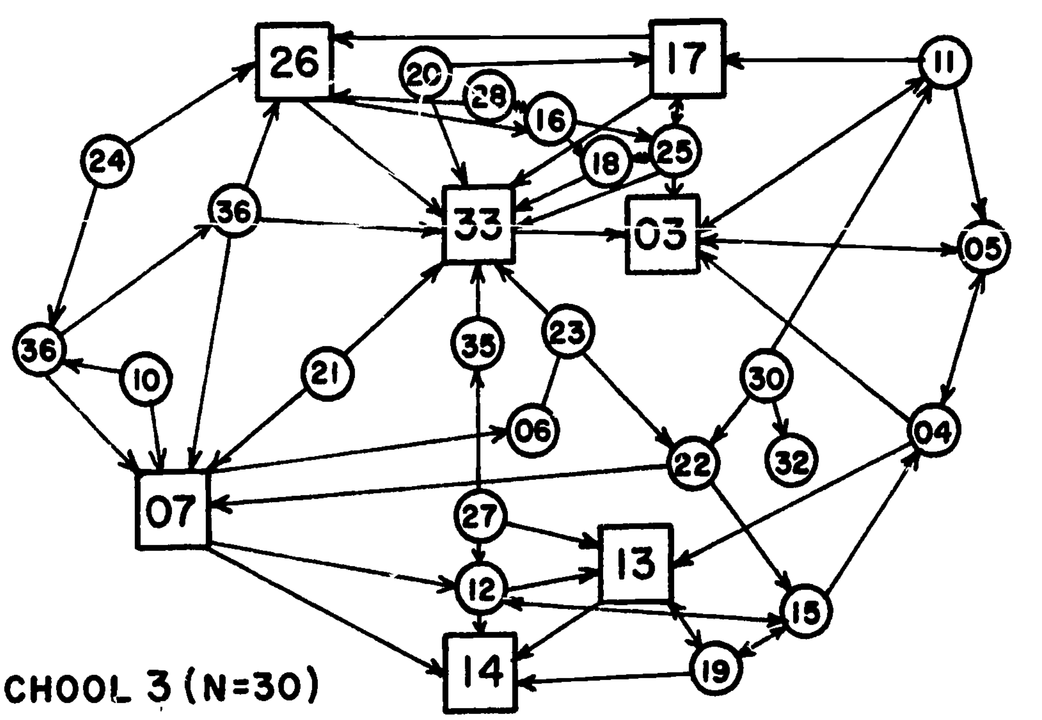

FIGURE 1-C: SCHOOL 3 (N=30)

LEGEND: □ : OPINION LEADER ○ : PRIMARY LIAISON △ : SECONDARY LIAISON ○ : TEACHER

FIGURE 1: SOCIOGRAMS OF (TEACHING) ADVICE COMMUNICATION NETWORK AMONG TEACHERS IN THE THREE SCHOOLS

isolates in School 3, there were three in School 1 (7%) and seven in School 2 (19%).

Number of minor cliques: A minor clique was defined as a subgroup of teachers who had no connections with the major clique (the major clique constituting the largest number of teachers who interacted with one another). The computational procedure is presented in Appendix D. School 3 had no minor cliques, School 1 had three and School 2 had one.

Number of Opinion Leaders: An opinion leader was defined as a teacher who was nominated by more than 10% of his fellow teachers. School 3 had seven opinion leaders (teachers 33, 17, 03, 07, 14, 13 and 26 in Figure 1-A). School 1 had two (teachers 44 and 29) and School 2 had none.

Number of primary and secondary liaisons: A primary liaison was defined as a teacher whose absence from the group structure would break one connected group into at least two separated subgroups, each consisting of at least two teachers. A secondary liaison was defined as a teacher whose absence, paired with the absence of another teacher, would break one connected group into at least two separated subgroups, each consisting of at least two teachers. A primary liaison cannot be counted as a secondary liaison and secondary liaisons must exist at least in pairs. There were no liaisons, either primary or secondary, in School 3. In School 1, teacher 27 was a primary liaison and teachers 29, 50, 57 and 38 were secondary liaisons. In School 2, teachers 15, 31, 32, 40, and 42 were primary liaisons, and teachers 45, 19, 23, 30, 05, 03, 13, 01 were secondary liaisons.

We have, in this section, seen some basic properties in the communication networks. Differentiation of the three structures was made in terms of isolation, minor cliques, opinion leader concentration, and liaisons whose absence could considerably increase the communication cost for some other teachers in the structure. In the next section, I will discuss measurements of teachers' influence and prestige in terms of the communication structure and I will try to determine whether influence and prestige were also consistent with innovativeness of the teachers in the schools.

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Influence Domain, Centrality and Prestige.

When teacher A seeks advice from teacher B, we may say that teacher B exerts some influence on teacher A. In the sociograms in Figures 1-A, 1-B, and 1-C, such relationships are indicated by the directions (note arrows) of the chains. In addition to the direct influence which teacher B may exert on teacher A, there is also the indirect influence he exerts on teacher C if teacher C is influenced by (seeks advice from) teacher A. This indirect influence of B upon C can be shown as C ⟶ A ⟶ B. The direction of the arrow indicates the direction of the influence. Thus, influence domain of a teacher was defined as the number of teachers to whom he provided advice upon request or whom he influenced indirectly.

To find the influence domain of the teachers, a distance matrix was called for. A distance matrix( ) has in each of its cells either (1) a positive integer indicating the number of chains in the shortest influence route between the two teachers, or (2) an ∞ (infinity) if such an influence route does not exist between the two teachers. Such a matrix can be obtained by applying matrix multiplication on the incidence matrix (the incidence matrix shows the communication network). A computer program including a routine to find the distance matrix for a given communication network (in incidence matrix form) was written and operationalized on IBM 7094 at the Johns Hopkins Computing Center. The main output features of the program at the present time include: (1) the distance matrix, (2) the influence domain of each element, (3) the centrality of each element (defined as the sum of all chains in the influence domain divided by the influence domain). The three communication network matrices of the schools were fed into the program to find the influence domain and centrality of each teacher (Results presented in Appendices B and C).

Prestige of a teacher, then, was operationally defined as the influence domain divided by the product of his centrality and the number of other teachers (N-1). It could range from 1 (most prestigious) to zero (least prestigious). Computational

Table 3

INFLUENCE DOMAIN, CENTRALITY AND PRESTIGE OF OPINION LEADERS

Communication Indices			
Opinion Leader	Influence Domain	Centrality	Prestige
School 3 (N=30)			
Teacher 03	26 (87%)	2.27	0.395
Teacher 33	26 (87%)	2.85	0.315
Teacher 17	26 (87%)	3.12	0.287
Teacher 13	26 (87%)	3.31	0.271
Teacher 14	27 (90%)	3.44	0.271
Teacher 26	26 (87%)	3.65	0.246
Teacher 07	8 (27%)	1.38	0.280
School 1 (N=42)			
Teacher 44	20 (48%)	1.60	0.305
Teacher 29	17 (40%)	1.82	0.228
School 2 (N=37)			
Teacher 03*	11 (30%)	2.18	0.140

* There were no opinion leaders, as defined in this study, in School 2. Teacher 03 was the most prestigious teacher and was presented here for comparative purposes.

procedures of these indices can be found in Appendix D.

The influence domain, centrality and prestige of the opinion leaders are presented in Table 3. We see here that the opinion leaders in School 3 not only had greater influence domain, but also tended to enjoy higher prestige than did those in School 1. As indicated earlier, there was no opinion leader in School 2; the most prestigious teacher (03) in the school obtained a score 0.140, far below those enjoyed by opinion leaders in Schools 3 and 1. Five of the seven opinion leaders in School 3 obtained a prestige index of more than 0.250 as did one of the two opinion leaders in School 1.

SUMMARY AND DISCUSSION

In this report, I tried first to indicate the relationship between conceptual schemes and research methods. Using a simplified and probably exaggerated example of a "typical" diffusion study, I pointed out the conceptual as well as methodological characteristics of such a study. Then, I proceeded to suggest a process view of the diffusion phenomenon and presented a number of neglected areas in diffusion research, among them the decision-making process, the gatekeeping functions, implementation of the innovation, and effects and consequences of the innovation. These conceptual reorientations led the discussion into "innovative methods" including the field experiment, computer simulation and structural analysis.

I then reported a study of a structural analysis of innovation diffusion among teachers in three Michigan high schools.

The data, summarized in Table 4, suggest that the educational organization (School 3) with the highest degree of innovation internalization and smallest variability in first awareness among the members (teachers) had a communication structure (wired wheel) superior to those (satellite and star structures) of the other two educational organizations. The superiority of the organization (School 3) is reflected by the fact that it had (1) no teachers who were isolated or disconnected from the communication network, (2) no minor cliques separated from the main

Table 4

COMPARISONS OF STRUCTURAL DIFFERENCES IN THE THREE SCHOOLS

Structural Property	School 1 (N=42)	School 2 (N=37)	School 3 (N=30)
Number of isolates	3 (7%)	7 (19%)	0 (0%)
Number of minor cliques	3 (7%)	1 (3%)	0 (0%)
Number of opinion leaders	2 (5%)	0 (0%)	7 (23%)
Number of primary liaisons	1 (2%)	5 (14%)	0 (0%)
Number of secondary liaisons	4 (10%)	8 (22%)	0 (0%)
Maximum influence domain obtained by a teacher	20 (48%)	11 (30%)	27 (90%)
Maximum prestige obtained by a teacher*	0.305	0.140	0.395

* The maximum possible prestige was 1.00.

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network, (3) no primary or secondary liaisons (which meant that the absence of one or two teachers, regardless how crucially positioned they might be, could not break the network into cliques). The tightly knitted structure (of School 3) was also evident in the number of opinion leaders whose influence domain covered nearly 90% of all members (teachers) and who enjoyed relatively high prestige among fellow members (teachers).

This preliminary study demonstrated that the diffusion phenomenon within organizations (schools) may be explained and predicted from certain structural properties. Further development along this line, such as complete inclusion of all members in the organization (which we failed to achieve in this study) promises to yield some powerful structural predictors for the process of innovation diffusion; predictors more precise than the correlational or number of "opinion leaders" approaches utilized so often in diffusion research.(7) Now, we should and can make an effort to study especially those who play liaison roles in the structure and who enjoy high prestige among fellow members in the structure. These are the persons who play important roles in determining the structure's communication cost which, in turn, is directly relevant to the introduction of and receptivity to the innovation in the social system.

What implications can such structural analysis have for educational organizations or policy makers attempting to innovate? There are at least three possibilities which I feel bear mentioning.

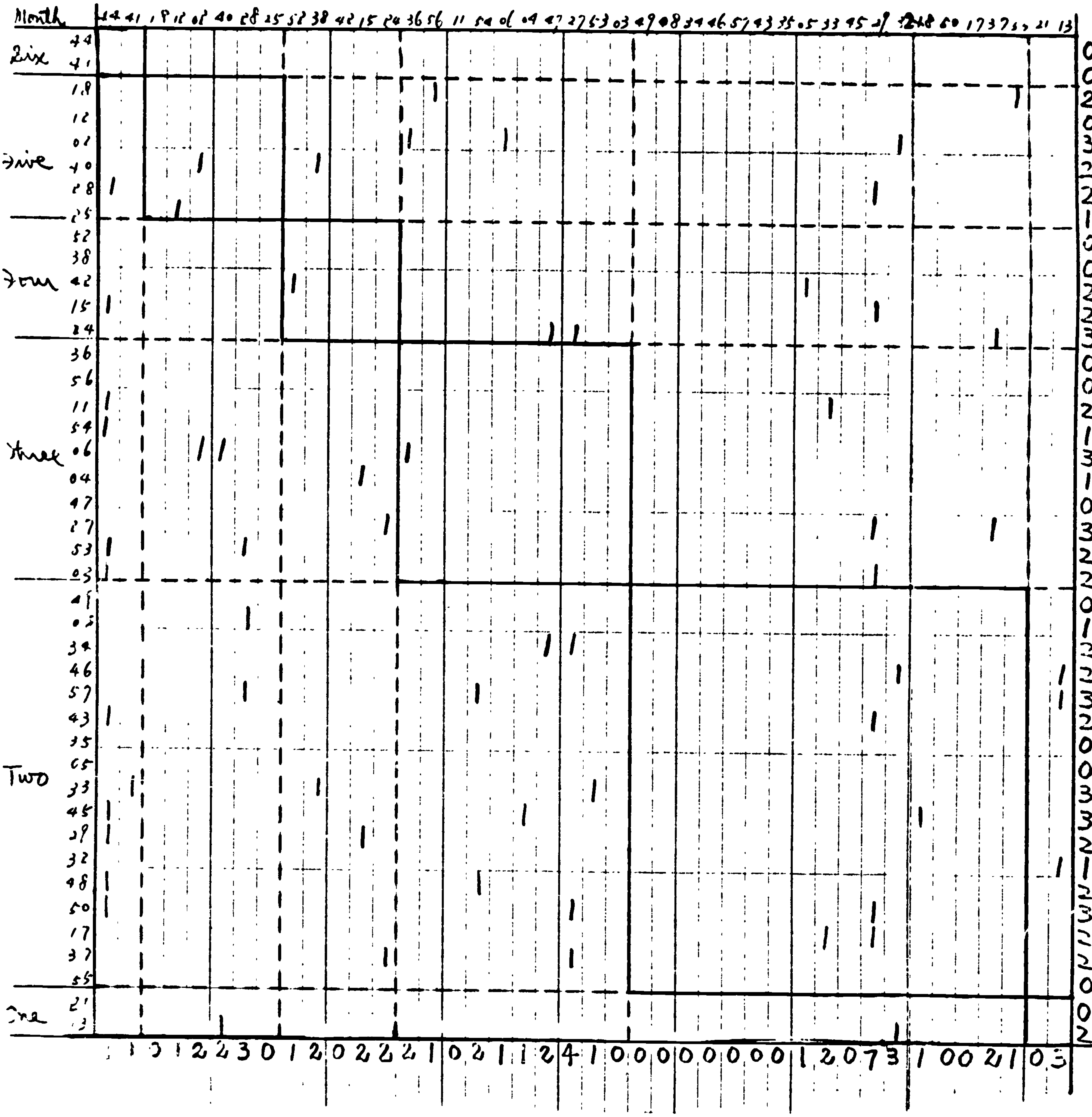
One, such structural analysis can provide information about the optimal process for disseminating new ideas and practices within an educational system. For example, to diffuse new educational practices and ideas into School 1, teachers 44 and 29 who enjoyed the highest prestige among the teachers should be initially invited to participate in discussions about these innovations and should be persuaded to support the use of the innovations in the school. In other words, the structural analysis should indicate who the gatekeepers are in an educational system and how they influence fellow workers. The organization if it hopes to have the innovation successfully introduced and implemented should strive to win over their support.

Two, the structural analysis may provide some information as to the compatibility between formal and informal structures in an educational system. When the two structures are found to be rather incompatible, it may be construed as a warning that conflict and failure will result if the innovations are disseminated through the formal structure. This may be the case regardless of how well the innovations may be intended for the system.

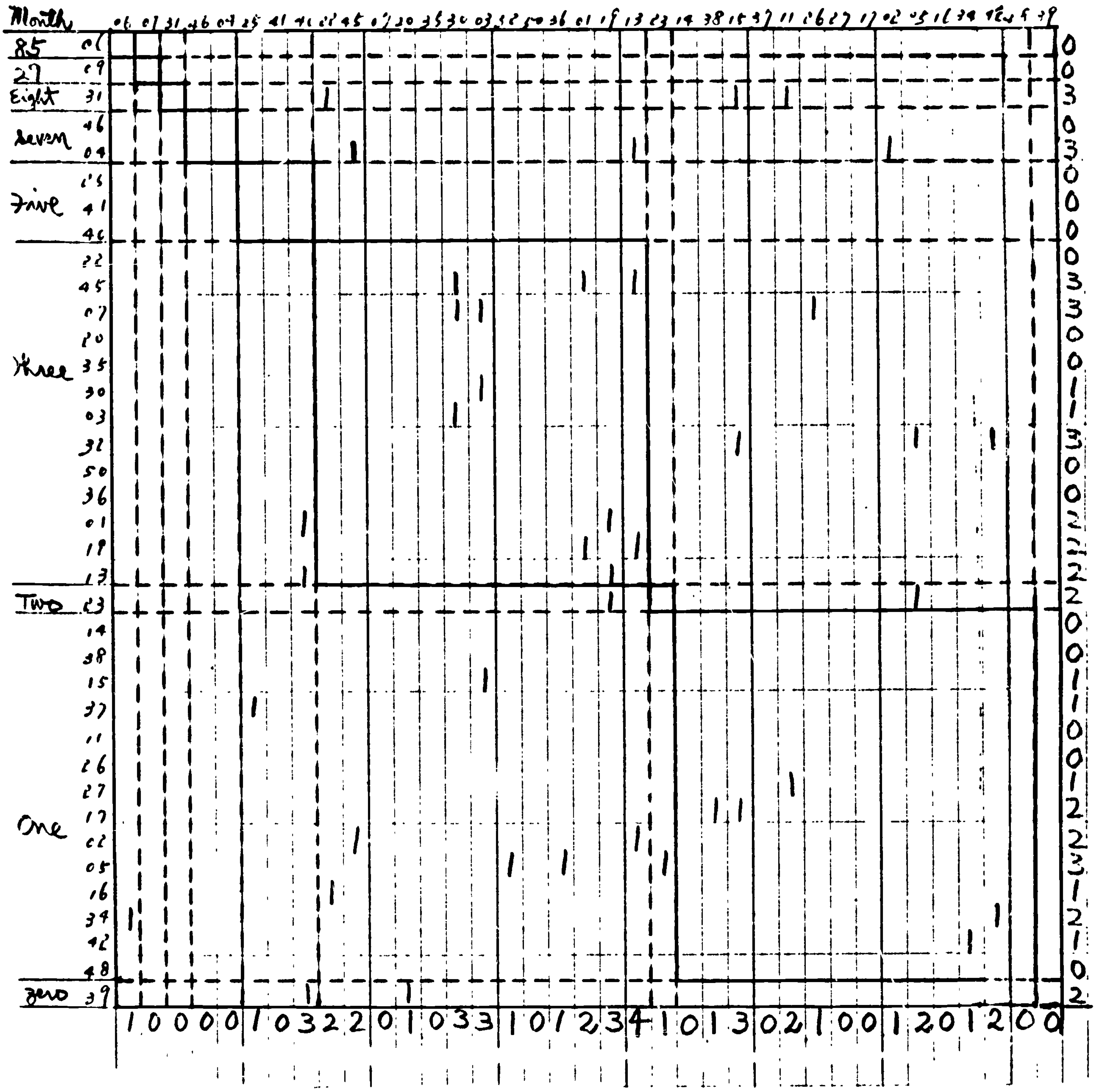
Finally, in addition to the advantage to us of being able to utilize the existing structure for optimal diffusion, such analysis may further be used to improve the structure for innovation assimilation. School 2 in our study, for example, is shown to be very inefficient for innovation assimilation. The responsible persons in the system should be advised of the situation and recommendations should be made as to how such structure might be changed socially and physically. It is crucial, too, to think of ways to bring the isolated teachers into the main clique. Communication among the teachers should somehow be made more frequent and regular. New routes of communication should be created among teachers. These changes could be achieved, for example, by the rearranging of the teachers' offices or by creating a working hall for all teachers.

We are still quite far from achieving a clear picture of the diffusion process of educational innovations. But as we widen our conceptual scope and utilize "innovative" methods to study the various crucial components, we should begin to understand the structure and the substance involved in the process and to discover ways of tackling the various problems and barriers. It is with this consideration in mind that I hope this report has initiated a fresh methodological stategy and conceptual framework for studying educational innovations in particular and educational change in general.

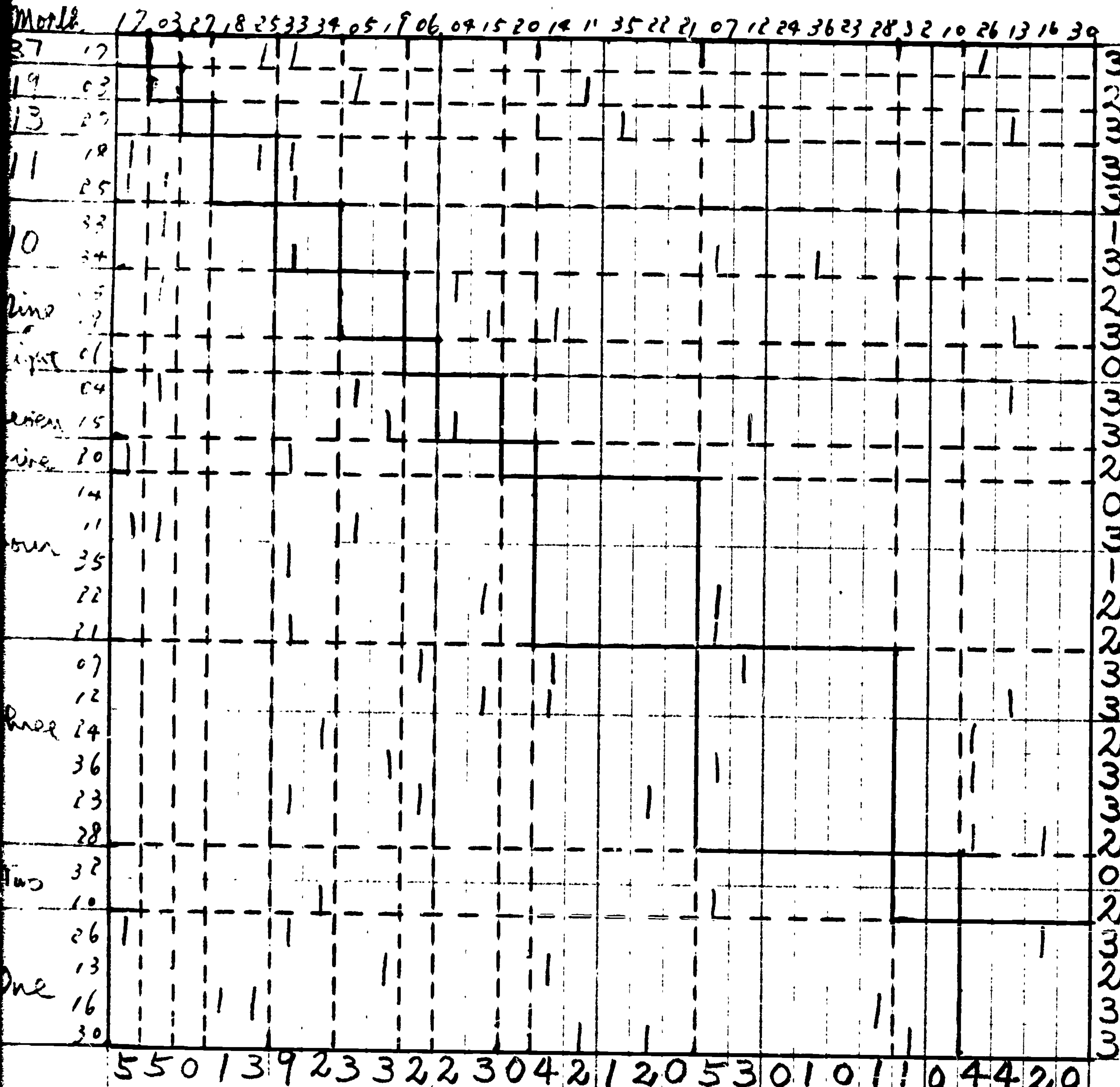
Appendix A-1: The Communication Matrix for Teachers in School 1 partitioned by Earliness of Innovation Awareness



Appendix A-2: The Communication Matrix for Teachers in School 2 partitioned by Earliness of Innovation Awareness



Appendix A-3: The Communication Matrix for Teachers in School 3 partitioned by Earliness of Innovation Awareness



Appendix B-1: The Distance Matrix for Teachers in School 1

	44	41	18	12	02	40	28	25	52	38	42	15	24	36	56	11	54	06	04	47	27	53	03	49	08	34	46	57	43	35	05	33	45	29	32	48	50	17	37	55	21	13
44																																										
41																																										
18															1																									1		
12																																										
02						2				3				1				1																	1							2
40					1					1				2				2																	2							3
28	1											2																						1								
25				1																																						
52																																										
38																																										
42									1																						1											
15	1																																	1								
24	3											3								1	1													2					1			
36																																										
56																																										
11	1	2					3			2		5										2										1		4								
54	1																																									
06					1	1				2				1																					2							3
04	2											1																						2								
47																																										
27	2											2	1							2														1					1			
53	1						1					3																						2								
03	1											2																						1								
49																																										
08	2						1					3																						2								
34	3											3	2							1	1													2					2			
46					3	2				3				4				4																	1							1
57	2				3	2	1			3		3		4			1	4																2	2							1
43	1											2																						1								
35																																										
05																																										
33	2	1					2			1		4										1												3								
45	1											2					2		1															3		1						
29	1											1																														
32					3	2				3				4				4																								1
48	1																1																									
50	1											2	2							3	1													1					2			
17	2	2					3			2		2										2										1		1								
37	3											3	1							2	1													2								
55																																										
21																																										
13					2	1				2				3				3																	1							

Appendix B-2: The Distance Matrix for Teachers in School 2

	06	09	31	46	04	25	41	40	22	45	07	20	35	30	03	32	50	36	01	19	13	23	14	38	15	37	11	26	27	17	02	05	16	34	42	48	39
06																																					
09																																					
31									1					3	2										1		1										
46																																					
04								2		1				2	3				2	2	1										1						
25																																					
41																																					
40																																					
22																																					
45								2						1	2				1	2	1																
07														1	1													1									
20																																					
35																																					
30															1																						
03														1																							
32								5						3	2			2	4	3	4	2			1							1		2	1		
50																																					
36																																					
01								1												1	2																
19								2											1		1																
13								1											2	1																	
23	5							3						5	4	2		2	2	1	2				3							1		4	3		
14																																					
38																																					
15														2	1																						
37						1																															
11																																					
26																																					
27																											1										
17														3	2									1	1												
02								2		1				2	3				2	2	1																
05	4							4						4	3	1		1	3	2	3	1			2									3	2		
16									1																												
34	1																																		1		
42	2																																	1			
48																																					
39								1				1																									

Appendix B-3: The Distance Matrix for Teachers in School 3

	17	03	27	18	25	33	34	05	19	06	04	15	20	14	11	35	22	21	07	12	24	36	23	28	32	10	26	13	16	30
17		2		3	1	1		3	6		4	7		6	3					8				3			1	5	2	
03	2			5	3	3		1	4		2	5		4	1					6				3			3	3	4	
27	5	3		1	6	2		4	2		3	2		2	4	1				1				8			6	1	7	
18		2			1	1		3	6		4	7		6	3					8				4			2	5	3	
25	1	1		4		1		2	5		3	6		5	2					7				4			2	4	3	
33	3	1		6	4			2	5		3	6		5	2					7				6			4	4	5	
34	2	2		4	4	1		3	2	2	4	3		2	3				1	2		1		4			2	3	3	
05	3	1		6	4	4			3		1	4		3	2					5				6			4	2	5	
19	5	3		8	6	6		3			2	1		1	4					2				8			6	1	7	
06																														
04	3	1		6	4	4		1	2			3		2	2					4				6			4	1	5	
15	4	2		7	5	5		2	1		1			2	3					1				7			5	2	6	
20	1	2		4	2	1		3	6		4	7		6	3					8				4			2	5	3	
14																														
11	1	1		4	2	2		1	4		2	5		4						6				4			2	3	3	
35	4	2		7	5	1		3	6		4	7		6	3					8				7			5	5	6	
22	5	3		8	6	6		3	2	2	2	1		2	4				1	2				8			6	3	7	
21	4	2		7	5	1		3	4	2	4	3		2	3				1	2				7			5	3	6	
07	6	4		9	7	7		4	3	1	3	2		1	5					1				9			7	2	8	
12	5	3		8	6	6		3	2		2	1		1	4									8			6	1	7	
24	2	3		3	3	2	1	4	3	3	5	4		3	4				2	3		2		3			1	4	2	
36	2	3		3	3	2		4	1	2	3	2		2	4				1	2				3			1	2	2	
23	4	2		7	5	1		3	3	1	3	2		3	3		1		2	3				7			5	4	6	
28	2	3		2	2	2		4	7		5	8		7	4					9							1	6	1	
32																														
10	4	3		5	5	2	1	4	3	2	4	3		2	4				1	2		2		5			3	3	4	
26	1	2		2	2	1		3	6		4	7		6	3					8				2				5	1	
13	6	4		1	7	7		4	1		3	2		1	5					3				9			7		8	
16	2	2		1	1	2		3	6		4	7		6	3					8				1			2	5		
30	2	2		5	3	3		2	3	3	3	2		3	1		1		2	3				5	1		3	4	4	

APPENDIX C-1: INFLUENCE DOMAIN AND CENTRALITY OF TEACHERS IN SCHOOL 1

Teacher	Influence Domain	Centrality*
44	20	1.60
41	3	1.67
18	0	0.00
12	1	1.00
02	6	2.17
40	6	1.67
28	6	1.83
25	0	0.00
52	1	1.00
38	10	2.20
42	0	0.00
15	17	2.53
24	4	1.50
36	7	2.71
56	1	1.00
11	0	0.00
54	3	1.33
06	6	3.00
04	1	1.00
47	5	1.80
27	4	1.00
53	3	1.67
03	0	0.00
49	0	0.00
08	0	0.00
34	0	0.00
46	0	0.00
57	0	0.00
43	0	0.00
35	0	0.00
05	1	1.00
33	2	1.00
45	0	0.00
29	17	1.82
32	6	1.50
48	1	1.00
50	0	0.00
17	0	0.00
37	4	1.50
55	1	1.00
21	0	0.00
13	6	1.83

*The maximum centrality score is "1" and 0.00 has replaced ∞ for convenient reading.

APPENDIX C-2: INFLUENCE DOMAIN AND CENTRALITY OF TEACHERS IN SCHOOL 2

Teacher	Influence Domain	Centrality*
06	5	3.00
09	0	0.00
31	0	0.00
46	0	0.00
[illegible]	0	0.00
25	1	1.00
41	0	0.00
40	10	2.30
22	2	1.00
45	2	1.00
07	0	1.00
20	1	1.00
35	0	0.00
30	11	2.45
03	11	2.18
32	2	1.50
50	0	0.00
36	3	1.67
01	8	2.13
19	8	1.75
13	8	1.88
23	2	1.50
14	0	0.00
23	1	1.00
14	5	1.60
37	0	0.00
11	2	1.00
26	1	1.00
27	0	0.00
17	0	0.00
02	1	1.00
05	0	0.00
16	0	0.00
34	4	2.50
42	4	1.75
48	0	0.00
39	0	0.00

*See footnote - Appendix C-1.

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APPENDIX C-3: INFLUENCE DOMAIN AND CENTRALITY OF TEACHERS IN SCHOOL 3

Teacher	Influence Domain	Centrality*
17	26	3.12
03	26	2.70
27	0	0.00
18	26	5.42
25	26	3.92
33	26	2.85
34	2	1.00
05	26	2.88
19	26	3.69
06	9	2.00
04	26	3.15
15	26	4.12
20	0	0.00
14	27	3.44
11	26	3.15
35	1	1.00
22	2	1.00
21	0	0.00
07	8	1.38
12	26	4.58
24	0	0.00
36	3	1.67
23	0	0.00
28	26	5.50
32	1	1.00
10	0	0.00
26	26	3.65
13	26	3.31
16	26	4.54
30	0	0.00

*See footnote - Appendix C-1.

APPENDIX D: COMPUTATIONAL PROCEDURES FOR THE INCIDENCE MATRIX, INFLUENCE DOMAIN, CENTRALITY, PRESTIGE AND CLIQUE IDENTIFICATION

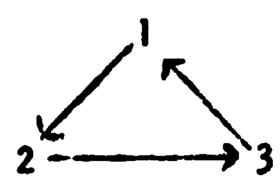
i. incidence matrix and distance matrix:

Sociometric data can be converted into a square incidence matrix in which the cells consist of values of 1's and 0's only. For a social system of n members, the matrix is a n by n matrix. Call this matrix A; then a_{ij} (row i and column j) is assigned a value of "1" if member i nominates member j and a_{ij} is assigned a value of "0" if member i does not nominate member j. The initial distance matrix, D, has also n by n cells, and an ∞ is assigned in all cells.

For instance, given the following initial incidence matrix and initial distance matrix:

$$A^1 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{matrix} 1 & 2 & 3 \end{matrix} \\ \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix} \end{array} \qquad D = \begin{array}{c} \begin{matrix} \; & 1 & 2 & 3 \end{matrix} \\ \begin{pmatrix} 1 & \infty & \infty & \infty \\ 2 & \infty & \infty & \infty \\ 3 & \infty & \infty & \infty \end{pmatrix} \end{array}$$

then, the network represented in A^1 can also be described in the following sociogram:



A^1, thus, shows the communication pattern of one-step (advice seeking) flow. We may say that member 1 exerts influence upon member 3, member 2 exerts influence upon member 1, and member 3 exerts influence upon member 2; all in one-step communication flow (or, direct influence). Then, we assign the value "1" (the number of steps) in cells d_{12}, d_{23}, and d_{31} in the distance matrix:

$$D = \begin{array}{c} \begin{matrix} \; & 1 & 2 & 3 \end{matrix} \\ \begin{pmatrix} 1 & \infty & 1 & \infty \\ 2 & \infty & \infty & 1 \\ 3 & 1 & \infty & \infty \end{pmatrix} \end{array}$$

In order to determine who exerts influence upon whom after two steps of communication flow or advice seeking activities, we square the A^1 matrix to obtain A^2 matrix. We compute, the values for each cell in A^2 with the operation of regular matrix multiplication first:

$$a_{ij}^{(2)} = (a_{i1}^1 \cdot a_{1j}^1) + (a_{i2}^1 \cdot a_{2j}^1) + \ldots + (a_{in}^1 \cdot a_{nj}^1)$$

$$= \sum_{k=1}^{n} (a_{ik}^1 \cdot a_{kj}^1)$$

Then:

$$a_{ij}^2 = \begin{cases} 1, \text{ if } a^{(2)} > 0 \\ 0, \quad a^{(2)} = 0 \end{cases}$$

Operating on the original matrix A^1 with the above formulas, we obtain matrix A^2:

$$A^2 = \begin{matrix} & 1 & 2 & 3 \\ 1 \\ 2 \\ 3 \end{matrix} \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

which indicates that after two steps of flow, the information or influence has been transmitted from member 1 to member 3 (via member 2), 2 to 1 (via 3), and 3 to 2 (via 1). Checking the distance matrix D against A^2 we find that the cells d_{13}, d_{21}, and d_{32} still have a value of infinity (∞). Thus, we assign a value of "2" (number of steps taken) into these cells. Now, the distance matrix D is:

$$D = \begin{pmatrix} & 1 & 2 & 3 \\ 1 & \infty & 1 & 2 \\ 2 & 2 & \infty & 1 \\ 3 & 1 & 2 & \infty \end{pmatrix}$$

Using the same procedure, we find that:

$$A^{(3)} = A^1 \cdot A^2$$

$$a^3_{ij} = \begin{cases} 1, & \text{if } a^{(3)}_{ij} > 1 \\ 0, & \text{if } a^{(3)}_{ij} = 0 \end{cases}$$

$$A^3 = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \end{array}$$

and the distance matrix D becomes:

$$D = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{pmatrix} 3 & 1 & 2 \\ 2 & 3 & 1 \\ 1 & 2 & 3 \end{pmatrix} \end{array}$$

which indicates that the distance between any two members is completely known. * In general, the maximum number of multiplications to be performed is n-1. In order to assure that the distance between any pair is minimum, d_{ij} can be assigned a value of m if and only if:

(1). $a^m_{ij} = 1$; and

(2). $a^k_{ij} = 0$ for all $k>m$

II. Influence domain, centrality, and prestige of members:

Influence domain of member 1 (I_i) is defined as:

$$I_i = \sum_{\text{all } k} d'_{ki} \quad \text{where} \quad d'_{ki} = \begin{cases} 1, & \text{if } d_{ki} < n \quad \text{and } k \neq i \\ 0, & \text{if } d_{ki} > n \end{cases}$$

*When "direct feedback" (loop) is not a crucial variable in an investigation, the diagonal cells should be assigned a value of "0" at all times. In this paper, the diagonal cells assumed "0" in all distance matrices.

Centrality of member i (C_i) is defined as:

$$C_i = \frac{\sum_{\text{all } k} d_{ki}}{I_i} \qquad \text{where } d_{ki} < n \qquad \text{and } k \neq i$$

And, prestige of member i (P_i) is defined as:

$$P_i = \begin{cases} \dfrac{I_i}{C_i\ (N-1)} & \text{when } C_i \neq 0 \\ 0 & \text{when } C_i = 0 \end{cases}$$

III. Clique identification:

Cliques can be identified from the distance matrix by the following procedure:

(1) First, select the member with the greatest influence domain:

$b_1 = \max\ (I_i;\ i=1, \ldots, n)$

(2) Clique 1 (G_1) consists of all members who are under b_1's influence:

$G_1 = \{d_{i1};\ d_{i1} < n,\ i = 2, \ldots, n\}$

(3) Then, select from the remaining members the member with the greatest influence domain:

$b_2 = \max\ (I\ ;\ i \text{ not in } G_1)$

(4) Clique 2 (G_2) consists of all members who are under b_2's influence:

$G_2 = \{d_{i1};\ d_{i1} < n, i = j, \ldots, n; \text{ where } j = n\ (G_1) \neq 2\}$

(5) Repeat steps (3) and (4) to find all cliques and the remaining members are isolates.

For a symmetric incidence matrix, a number of members may possess multiclique memberships. However, if the incidence matrix is symmetric (assuming reciprocity of communication between any nominating and nominated pair), it will not occur. In this paper, symmetric matrices were used in identifying the cliques in the schools.

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