THE UNIVERSITY OF ALBERTA

TOWARD A THEORY OF LIVING SYSTEMS IN MATHEMATICS EDUCATION

by

Ann Gladys Anderson

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NAME OF AUTHOR: Ann Gladys Anderson

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Ann Anderson

P.O. Box 250
Spaniard's Bay, Newfoundland
Canada
AOA 3XO

Date: 13 April 1987

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Toward a Theory of Living Systems in Mathematics Education", submitted by Ann Gladys Anderson in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

.... Supervisor

....

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....

External Examiner

Date: Oct 21/86..........

DEDICATION

This thesis is dedicated to my parents and to my daughter, Terri.

ABSTRACT

Incongruencies between the elementary mathematics curriculum and the mathematics discipline, as well as recent paradigm shifts evident in other disciplines, led the researcher to develop a model of mathematics education based on a "living systems" metaphor and embedded in the context of a small enrichment group. During the actualization of the "living systems" metaphor, the design of this study emerged such that three contexts -a regular grade four classroom, a "tutorial" small group, and an "enrichment" small group - were accessed by the researcher. Over a period of two and one-half months , the researcher observed the children in a regular classroom, as well as played a teacher/researcher role in small group sessions with a subgroup of six children.

Throughout the study, the researcher consciously attempted to incorporate Prigogine's dissipative structures in the small group settings, although external constraints greatly affected the evolution of the "tutorial" setting. Video tapes, and researcher's journals were used recursively on a daily basis throughout the data collection period to inform the development of the research.

Upon completion of the field work, in depth review of the data with respect to Prigogine's "thermodynamic" states of equilibrium revealed that the enrichment setting, the regular classroom and the tutorial setting exhibited characteristics similar to far from equilibrium, at equilibrium and near equilibrium systems respectively. Data analysis, per se, focused on the explication of autopoiesis - both individual and social - in each of these "states of equilibrium", and through this lens the presense of a "living systems" metaphor was further assessed.

From the findings, it was concluded that the "living systems"

metaphor was actualised. Specific conclusions concerning "boundaries", "heterogeneity", and other characteristics of living systems were also made. In particular, the researcher concluded that autopoiesis, although not necessarily a "whole group" phenomena, was enhanced in a far from equilibrium system. Overall, it was evident that the "living systems" metaphor was a viable framework for both the development of an alternative mathematics curriculum and an alternative research method for the study of such curriculum issues.

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CHAPTER I

INTRODUCTION

> Influenced by what he was taught in school, the average person regards mathematics as a series of techniques of use only to the scientist, the engineer and perhaps the financier. The reaction to such techniques is distaste for the subject and a decision to ignore it (Kline, 1953, p. 3).

The Mathematics Curriculum and the Mathematics Discipline

School mathematics, especially at the elementary level, has been - and for the most part, still is - dominated by arithmetic and Euclidean geometry and viewed by most as a rigid, non-creative pursuit in precision. As Kline indicated above, it has been a subject filled with meaningless procedures presented as truths to students who were oblivious to its nature. In contrast, mathematics as a discipline is a growing, changing phenomena. Its character is neither stagnant nor unidimensional; rather it is a vast and dynamic area of knowledge.

Smith (1951), after describing the developments in mathematics up to the close of the seventeenth century, made the following observation:

> By that time arithmetic as we ordinarily speak of it, referring to operations with numbers for commercial and industrial use, was practically what it is today. We have changed the way of teaching it and we have added new applications from time to time as requirements of business dictated; but the mathematical part of the subject has been nearly static. We even preserve certain traditional topics and methods that might profitably have been discarded long ago. . . Elementary geometry as ordinarily taught to beginners has made no advance, although, scientifically speaking, the foundations have been explored. . . . Euclidean geometry is what it was then; it has been rearranged for educational purposes. . . . Geometry has made giant strides, but not in the field that teachers generally cultivate, in secondary schools. . . . (pp. 444-445).

Since, some thirty years later, this description is still very fitting, it is evident that the subject matter intended for teaching in elementary schools does not correspond to the subject matter developed by the mathematics community at large. However, as Freudenthal (1973) indicated, not every advance of the mathematics discipline is appropriate or even desirable for learners at particular stages of their lives. Rather, images of "what mathematics is" to the mathematician may provide valuable insights into "what mathematics might be" to our students. That is, the discipline of mathematics and its curriculum counterpart, elementary school mathematics, differ significantly not only at the "content level", but also with respect to the underlying motives which drive their development.

Within the context of the mathematics discipline, mathematics is a dynamic, living and growing field of ideas and imagination; within the school context, it is a static, inanimate and completed body of knowledge - "facts and skills". As Kline's (1953) analogies suggest, mathematics is much more than algorithms and basic facts which are seen as ends in themselves.

> . . . The subject is not a series of techniques . . . they fall short of representing mathematics as color mixing does painting. The techniques are mathematics stripped of motivation, reasoning, beauty and significance. . . .
>
> To describe mathematics as only a method of inquiry is to describe de Vinci's Last Supper as an organization of paint on canvas. Mathematics is also a field for creative endeavour. . . .
>
> If insight and imagination, symmetry and proportion, lack of superfluity and exact adaption of means to ends, are comprehended in beauty and are characteristic of works of art, then mathematics is an art with a beauty all its own. . . . The language of mathematics is carefully, purposefully and often ingeniously designed. By virtue of its compactness it permits the mind to carry and work with ideas which expressed in ordinary language would be unwieldy. . . .
>
> Mathematics is more than a method, an art, and a language. It is a body of knowledge with content . . . that has undeniably, if sometimes imperceptibly, shaped the course of modern history. . . .
>
> In its broadest aspect mathematics is a spirit, a spirit of rationality. It is this spirit that challenges, stimulates, invigorates and drives human minds to exercise themselves to

the fullest (pp. 4-10).

Since we, as mathematics educators, are concerned with the teaching and learning of mathematics in the twentieth century, for use and continual development in the twenty-first century, we need to seek alternatives in an attempt to emancipate ourselves from a curriculum and attitude which predates that of the mathematics discipline itself. Mathematics educators must rise to the challenge to develop a mathematics curriculum which attempts to provide pupils with the most satisfying, fundamental and fulfilling mathematical experience possible.

A Search For Alternatives

> A paradigm is a loose collection of logically held together assumptions, concepts or propositions, that orient thinking and research . . . a way of looking at the world, the assumptions people have about what is important and what makes the world work . . . (Bogden and Biklen, 1982, p.30)

Over the past few decades, many of the scientific disciplines have experienced a change in world view, a paradigm shift. Numerous authors who explicate a "new" paradigm agree that the "Newtonian legacy", i.e. the world view of classical physics, is no longer comprehensible enough to solve present day problems. Therefore, these authors advocate a change in our very way of thinking about and perceiving the world. Like Capra (1982), they feel that

> . . . high inflation and unemployment, energy crisis, crises in health care, pollution and other environmental disasters, rising wave of violence and crime . . . these are all different facets of one and the same crisis, and that crisis is essentially a crisis of perception. Like the crisis in Physics in the 1920s, it derives from the fact that we are trying to apply the concepts of an outdated world view - the mechanistic world view of Cartesian-Newtonian science - to a reality that can no longer be understood in terms of these concepts. We live today in a globally, interconnected world, in which biological, psychological, social and environmental phenomena are all interdependent. To describe this world appropriately we need an ecological perspective which the Cartesian view does not offer (pp. 15-16).

As a consequence of such 'global rethinking' within the disciplines, a new discipline called general systems theory has evolved. Within this context, principles which apply to systems in general have been derived. As Bertalanffy (1968), the originator of general system theory, stated, "we must think in terms of systems of elements in mutual interaction" since the classical physics approach which dealt with "isolable units acting in one-way causality has proved to be insufficient" (p.45). As a result of such shifts, modern science has come to recognize and explicate such notions as "wholeness", "organization", "dynamic interaction" and "systems".

Of particular concern is the significance which such a paradigm shift might hold for the field of education. Clark (1972) argued

> In view of the fact that today's educators were reared and educated in natural and conceptual worlds which are suddenly becoming outmoded, it is not surprising to find many schools and colleges geared more to the past than the future. . . . However, pressure stemming from threats to our civilization are building upon us . . . to do everything possible to help educators become acquainted with . . . general systems theory (pp. 170-171).

Therefore, if for no other reason but to awaken ourselves from an outdated mode of thinking, educators need to explore the potential of the new paradigm in a search for alternatives which are fundamentally different from the present "Newtonian model" and congruent with the "modern view". Even more so, however, since education involves children and teachers in mutual interaction, rather than isolated parts, the systems view provides a more conducive frame of reference. Indeed, Sawada and Caley (1985, 1986) have developed new metaphors for education which incorporate various concepts discussed within the "new world view".

The equivalence between mathematics proper and the "systems view" was also a significant consideration. Influenced by the creativity, interconnectivity and dynamics experienced within the mathematics discipline, a search for alternatives for mathematics education aptly led to "general system theory". Davis and Hersh (1981) even suggest that "the notion that creative mathematical work could ever be mechanized seems, to many mathematicians, demeaning to their professional self-esteem"(p. 15). Yet, in the Newtonian model perpetuated within the school mathematics, that is exactly what has occurred. Thus, to seek an alternative for mathematics education which compares with the "essence" of its parent discipline, mathematics educators need to grasp the opportunity to participate in the current paradigm shift. Since the seeds of such a world view are inherent in mathematics proper , in that,

> A sense of strong personal aesthetic delight derives from the phenomena that can be termed order out of chaos. To some extent the whole object of mathematics is to create order where previously chaos seemed to reign, to extract structure and invariance from the midst of disarray and turmoil (Davis and Hersh,1981,p. 72).

mathematics education should also incorporate the "systems view" into its development.

The "Newtonian" And "Systems" World Views

Before pursuing the implications of a paradigm shift in mathematics education, we need to ascertain the characteristics of the "opposing" world views. What exactly constitutes this "new" paradigm of science currently visible in modern physics, biology and psychotherapy? A perusal of the literature reinforces the diverse backgrounds from which it has evolved. Capra (1982) uses the term "ecological perspective"; Jantsch (1979) describes a "theory of co-evolution"; Durkin (1981) speaks of "general systems theory"; Maruyama (1974b) discusses the "mutual causal paradigm"; Prigogine and Stengers (1984) deal with "dissipative structures"; and Sawada and Caley (1986) speak of "recursive complementarity". Although the terms differ, many common themes pervade all of these interpretations such that a synthesis and elaboration of the "new" paradigm can be appropriately discussed under the umbrella of "general systems theory". However, this more recent world view becomes even more striking when juxtaposed with the "old" paradigm of classical physics.

Under the Newtonian paradigm, an analogy used for the 'universe' was that of a "well oiled machine". This mechanical system was reducible to fundamental building blocks whose properties and interactions determined all natural phenomena. As with any machine, it was believed that the parts made up the whole, and each part could be isolated and observed or maintained separately and independently. If the machine was not functioning well, it was simply a matter of locating the particular piece that was broken, fixing it and thereby mending the whole mechanism. This Newtonian paradigm was also extended to living organisms and they too were considered to be similar to machines. Such a mechanistic, technological world view has led to the "well-known fragmentation in our academic disciplines and government agencies. . . . " (Capra, 1982, p. 40).

The general systems theory, on the other hand, focuses on the interrelatedness and interdependence of all phenomena. Properties of the whole system cannot be reduced to those of its individual parts. The emphasis is on principles of organization and process because "systems thinking is a holistic, synergistic point of view" (Durkin, 1981a, p. 8). There is a hierarchial structure wherein systems play roles of both parts and wholes and whereby subsystems are parts of systems, which are subsystems of suprasystems and so on. Such a systemic view of the world leads to interconnectivity and ecumenical, global relations throughout our society.

As Doll (1986) pointed out:

> . . . In terms of curriculum and behaviorist learning theory the same simple assumptions hold : Pupils learn that which is taught; the curriculum is seen as a linear "course to be run". Prigogine and Stengers (1984), like others who have criticized this Newtonian view, see it as more simplistic than wrong. . . . In place of this simplicity they offer a world which is complex, self-organizing, and unpredictable (pp. 11-12).

Interestingly, the parallellism between these two paradigms is reflected well in the relations between the mathematics curriculum and its parent discipline. The present day curriculum is but an explication of the "Newtonian world view" wherein mathematical concepts are isolable units which when joined together at some later stage are expected to produce an understandable whole. In contrast, mathematics proper reflects the "systems world view" where concepts are interconnected and the whole is much more than the sum of the parts. It seems timely then that we pursue the potential such a world view offers our elementary school mathematics currriculum.

CHAPTER II

BACKGROUND TO THE STUDY

Living Systems

Since the learning of mathematics as well as the doing of mathematics is a human pursuit involving active participants, the search for alternatives was focused on the developments of "living systems" which have occurred under the umbrella of general systems theory.

> The fundamental principle of living systems is that the essence of being alive is isomorphic across all levels of living systems: it matters not whether one is dealing with cells, elephants, planets or the universe; the life of each system is fundamentally the same . . . (Caley and Sawada, 1986, p.5).

It is proposed,then, that the system of learner and mathematics might be conceived as a "living system" and that the "living systems" metaphor be an appropriate one for mathematics education. To pursue such a possibility it is essential to comprehend the characteristics of what it means to be "living". Capra (1982) aptly describes a living organism in terms comparable to that of Jantsch (1979):

> . . . A living organism is a self-organizing system which means that its order in structure and function is not imposed by the environment but is established by the system itself. . . .
>
> Living organisms . . . are open systems which means . . . they . . . maintain a continuous exchange of energy and matter with their environment. . . .
>
> [This] allows the system to remain in a state of non-equilibrium, in which it is always "at work". . . . Living organisms are open systems that continually operate far from equilibrium. . . . (pp. 269-270).

Hence, we have a view of the living organism which recognizes its active and dynamic properties and does not see it as simply a "reactive" organism. Durkin (1981b) extends the notion of living systems still further with his model of a "self-referential autonomous living structure". The four characteristics such structures possess are:

> . . . 1) Living structure describes its own structure by closing informational boundaries around itself, thus distinguishing itself from its environment and other living structures. . . .
>
> 2) Living structure transforms its own structure by opening its boundaries to the flow of matter/energy between itself and the environment, as well as between itself and other living structures. . . .
>
> 3) Living structure generates operational configurations based on the basic opening and closing operations working in complementarity which achieve functions of wholeness, self-regulation and progressive self-transformation.
>
> 4) Living structure utilizes boundarying operations to create hierarchial divisions within itself. . . . Living whole and parts freely redefine themselves through the autonomous boundarying operation (p. xix).

A key notion of this concept of living systems is the "boundarying" or exchanges with the environment and other living structures. It is clear that the boundary conditions of living organisms are not rigid but are instead permeable structures which are created by the organisms themselves. They are not imposed by an outsider. When Bertalanffy (1968) discussed "open systems", he coined the term "equifinality" to describe the process whereby such a system may reach the same final state from different intial conditions and in different ways. This phenomenon of equifinality parallels the many to one mappings in mathematics, thus implying there is more than one path leading towards a goal. Hence, a living structure "improvises ways to utilize opportunities currently available, as it moves toward goals which are unpredictable from initial conditions; indeed the specific path towards the goal cannot be predicted either" (Durkin, 1981a, p. 17). The determinism of the Newtonian legacy is replaced by such improvised compensatory actions which arise in response to perturbations within the system.

Of particular concern when we examine "open exchange" phenomena are the feedback mechanisms, i.e. interactions, incorporated by the living system. Proponents of the general systems theory espouse mutual and reciprocal causality rather than one-way cause-effect relationships. That is, living systems simultaneously affect one another through their interactions, thus both are continuously changing due to mutual causality. It is not possible to isolate one event which "caused" an outcome as was supposed by the previous paradigm; events are too entangled to do so. Of specific importance here are the notions of positive and negative feedback found in cybernetics. Cybernetics is a field which began as one concerned mainly with "control theory" with an emphasis on negative feedback and evolved to the point where authors such as Maruyama (1963) spoke more of positive feedback and its amplifying nature. Within Maruyama's mutual causal paradigm, heterogeneity, symbiosis and reciprocity are key ingredients. Through this notion of deviation-amplification, i.e. positive feedback, a living system does not necessarily move toward disintegration but rather toward creation in the sense that interactions may cause the system to leap to even higher levels of organization. As Durkin (1981a) indicates ". . . positive feedback will become a signal to the members to amplify their patterned exchange while negative feedback will signal the need for changing the pattern, in line with the new goals" (p. 18). Therefore, positive feedback is often equated with generating actions while negative feedback is equated with regulating actions. In other words, the former pushes a system far-from-equilibrium while the latter maintains the equilibrium state.

The significance of positive feedback for living systems, even though recognized by Bertalanffy (1968), did not receive serious attention until the seventies when Prigogine's work in non-equilibrium thermodynamics wherein new order, called "dissipative structures", could and did emerge from chaos, was widely recognized. That is, he " found that open systems far-from-equilibrium in a state of turbulence often gave rise to unexpected new structure" (Sawada and Caley,1986, p.6). In a recent work, Prigogine and Stengers (1984) not only discuss "dissipative structures" but also deal with the nature of self-referential systems. However, before elaborating on these concepts, a final concept used in the living systems theory, that of autopoiesis, requires mentioning.

Autopoietic systems are living systems which continuously renew themselves such that the integrity of the structure is maintained (Jantsch, 1979, p. 7). More specifically, Gray (1981a) describes it as follows:

> The autopoietic organization is defined as a unity by a network of production of components which : 1) participate recursively in the same network of productions of components which produced these components, and 2) realize the network of productions as a unity in the space in which the components exist (p. 297).

Indeed, Maturana and Varela propose that "autopoiesis is a necessary and sufficient character of the organization of living systems" (Varela, 1979, p.17)

Dissipative Structure and Autopoiesis : A Closer Look

The preceding perusal of the literature led this researcher to view Prigogine's and Maturana's theories as fundamental to living systems. Consequently, in order to fully explicate the "organization" of a living system, their ideas are discussed in depth.

Prigogine and Stengers (1984) deal with open systems which are in constant exchange with their environment. They speak of the "self-organizing processes in far-from-equilibrium systems" corresponding to a "delicate interplay between chance and necessity, between fluctuations and deterministic laws" (p. 176). It is in this respect that the notion of "bifurcation point" was needed. At such a point, there are numerous paths a system might follow, hence the chance component; once a path is chosen, it is followed until another bifurcation point is reached, hence a sense of determinism. Under far-from-equilibrium conditions (FFE) , it was clear that at such bifurcation points, dissipative structures could emerge. The term "dissipative structures" was coined to indicate the complementarity between dissipation on the one hand and structure on the other. Prigogine and Stengers thereby indicate that entropy can be a source of creation. Turbulence or chaos, rather than seen as a negative anomally was now viewed as potential for the creativity of new organization and it was further believed that such possibilities were widespread.

In their discussions of such non-equilibrium systems, they offer by contrast, a look at systems at equilibrium (AE) and near equilibrium (NE) as well. In the latter, Prigogine and Stengers (1984) illustrate that the systems parameters are set externally (as in the setting of a thermostat) and organizing processes entail small corrections to deviations from such preset parameters so that the stability is maintained and the system is brought back to equilibrium. On the other hand, the parameters of a far-from-equilibrium system are in constant flux and even though a steady state may be reached it is not predictable. Instead, as systems approach far-from-equilibrium conditions, they are subject to spontaneous reordering. The significance of the initial conditions differ for these types of systems as well. At FFE, the initial kick triggers but does not determine the outcome. Whereas AE or NE, whatever the initial conditions, the system will finally reach the state imposed by the boundary conditions.

Prigogine and Stengers (1984) , further indicate that FFE an individual can make a difference whereas AE or NE, the individual is insignificant with respect to the global state. In other words, AE and NE, molecules (components) behave as individuals unaware of the others in the system, yet FFE, the behavior of individual molecules (components) seems to be informed by the overall state of the system. Also, within FFE systems, irreversible processes occur and we witness the emergence of highly specific states; whereas, within AE and NE systems, universal laws can be applied to deduce the system's overall behavior. Under FFE conditions "fluctuations may lead to new behavior, different from the 'normal' stable behavior characteristic of AE and NE systems" (p. 141). In summary, then, as Prigogine and Stengers (1984) posit:

> The interaction of a system with the outside world, its embedding in nonequilibrium conditions, may become . . . the starting point for the formation of new dynamic states of matter - dissipative structures. . . . (which) are essentially a reflection of the global situation of nonequilibrium producing them (pp.143-144).

Interactions and relations between components is also of major concern to Maturana and Varela (1980). These authors indicate that since they are interested in the organization of living systems, they are not concerned with the "properties of components" of such systems but rather with "processes and relations between processes realized through the components" (p. 75). In particular, these authors explicate the concept of autopoiesis which they define as:

> An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in the space in which they (the components) exist by specifying the ontological domain of its realization as such a network (Maturana and Varela, 1980, pp. 78-79).

In essence then an autopoietic system is a self-generating system which specifies its own organization by recursively producing its own components so that perturbations are constantly compensated for while always maintaining its organization as an invariant. Maturana and Varela (1980) further elaborate the consequences of autopoiesis and in doing so contrast it with allopoiesis :

> . . .(1) Autopoietic machines are autonomous; . . . they subordinate all changes to the maintenance of their own organization, independently of how profoundly they may otherwise be transformed in the process . . . allopoietic machines have as a product of their functioning something different from themselves . . .
> (2) Autopoietic machines have individuality; . . . by keeping their organization as an invariant . . . they actively maintain an identity that is independent and yet makes possible their interactions with an observer. Allopoietic machines have an identity that depends on the observer and is not determined through their operation . . . Allopoietic machines do have an externally defined individuality . . .
> (3) Autopoietic machines are unities . . . their operations specify their own boundaries in the processes of self-production. . . . Allopoietic machines, whose boundaries are defined completely by the observer, who, by specifying its input and output surfaces, specifies what pertains to its operation.
> (4) Autopoietic machines do not have input or outputs. They can be perturbed by independent events and undergo internal structural changes which compensate for these perturbations . . . (p.80-81)

The issue of perturbations is significant, and any deformation within an autopoietic system "is compensated for, not by bringing the system back to an identical state in its components" but by maintaining the coherence of the system "as defined by the relation of productions that constitute autopoiesis" (p.93). That is, the system rather than returning to some "equilibrium state" proceeds to transform under the perturbations while simultaneously maintaining its coherence as a system. Maturana and Varela (1980) also address the concept of coupling which is similar to Maruyama's (1974b) mutual causal paradigm. According to Maturana and Varela, two or more unities are coupled when the conduct of one is a function of the conduct of the other. Accordingly, such coupling results from mutual modification which interacting unities undergo without a loss of identity. They also propose that such coupling of autopoietic systems may lead to the constitution of a new unity while the individual paths of each 'become reciprocal sources of specification of each other (p.108). In this light, Maturana indicates his support for the concept of social autopoiesis which is upheld by Beer who writes in the Preface to Maturana and Varela (1980):

> . . . yes, human societies *are* biological systems. Moreover I claim that this book conclusively proves the point. . . . one of those readings was exclusively devoted to validating this contention . . . The outcome . . . says that any cohesive social institution is an autopoietic system- because it survives, because its method of survival answers the autopoietic criteria, and because it may well change its entire appearance and its apparent purpose in the process. As examples . . . schools and universities . . . (p.70)

The key ingredients then for autopoiesis include the idea of "component production processes" and the "generation of a boundary". An autopoietic system generates its own boundary through dynamics such that the boundary thus created in turn creates the conditions required for such dynamics. Thus this "recursive and nested nature of autopoiesis" although "antithetical to deduction and linear thinking" (Sawada and Young,1986,p.7) is its very essence.

Overall then, living systems are autonomous, self-organizing, self-generating, self-referential structures. They are "open" systems far from equilibrium, which through recursive interaction, are able to transform themselves. The formation of such dynamic structures are indeterministic and necessarily spontaneous; indeed, perturbations serve as the impetus for its creativity. As Bertalanffy (1968) recognized, isomorphisms do exist; in this case, FFE systems, autopoietic systems and living systems, are isomorphic.

The Significance of Living Systems to Education

It has been previously argued that the gap between the mathematics discipline - which reflects a holistic view where relationships and interdependencies between the "parts" are of utmost concern- ,and school mathematics ,- which represents the Newtonian paradigm in its present fragmented form -, suggests the need for an orientation toward a new paradigm. As Rifkin (1981) indicated:

> Our entire learning process is little more than a 12-16 year training program for the Newtonian World View. In school, emphasis is placed on quantities . . . but rarely on qualities or conceptions. . . .
>
> Learning has become fragmented into tinier and tinier frameworks of study on the Newtonian assumption that the more we know about the individual parts, the more we will be able to make deductions about the whole. . . . As we begin to make a transition . . . our current approach to education and learning will be rendered obsolete. . . . Learning as progress will be replaced with learning as the process of becoming (pp. 226-229).

Certainly, the issue of "progress" deserves closer scrutiny. Because of it, learning is usually done for "someone else"; it is outwardly judged by others rather than by the learner; inner satisfaction, internal growth is paid lip service but the concept of learning as "becoming" as of yet holds little value. To the contrary, now seems to be the appropriate time to acknowledge that learning is a personal endeavour; its goal is not to "swallow" pieces of information to "regurgitate". As Laszlo (1972) warns, "the knowledge explosion . . . makes it imperative that newer conceptual models of instruction be developed" (p. 143). Even if we still believed that accessing and storing current information was "learning", the enormous proliferation of information in our world would render us inoperable to fulfill the task. Certainly, then, the "lineal model", in which the teacher taught, the student learned, is obsolete. Bateson (1981) suggests it became so with the appearance of "cybernetic circuits of interaction" (p.

134) and instead, Bateson connects "evolution and learning" pointing out that both must be "necessarily divergent" (p. 162). Thus, implying that education must be an open, dynamic and personal process.

Cybernetics II as discussed by Maruyama (1963) is also relevant to education. For instance, Maruyama maintains that creativity involves opportunities and skills for "idea exchanges between persons and the interaction of concepts within one person's mind" (p. 252). He further posits:

> As for the *contents* of the education, a greater part of education needs to become a *process* of developing the ability for exploration and skills for *self-education* in the student rather than storage of information in the student's head (Maruyama, 1972, p. 119).

To develop such a philosophy one need ascertain the relation of such metaphors to social contexts, and in particular, to the classroom. Zeleny (1985) suggests that "living systems cannot be understood and should not be studied apart from the social systems they create and on which they are dependent" (p. 125). In this sense, it is significant not to separate the learner from the learning environment. In discussing Maturana's notion of a "natural social system", Zeleny (1985), in contrast, points out that in artificial social systems, the imposed structure affects the rules of conduct but the rules themselves do not generate the structure. The parallelism of such artificial social systems with that of the traditional classroom is striking. The imposed structure of straight rows of individual seats and the authoritarian teacher certainly affects the conduct of the learners but as Zeleny (1985) suggested, in such social systems once the "pressure of the designer is removed", that is, the teacher leaves the class or new grouping formations are introduced, the "whole social system disintegrates" (p.125).

Doll (1986) proposed a "transformative curriculum" as an educational model which exemplified "Prigogine's open system paradigm". As Doll indicated

> The educational model that follows would be a transformative curriculum, with the individual and his or her structures or levels of understanding transformed. Such a change would be internal and include disequilibrium as a prime motivator, as well as the opportunity for self-regulation to work (p. 15).

Sawada and Caley (1985) also devised new metaphors for education using Prigogine's dissipative structures wherein learning is "becoming", and creativity is viewed as order emerging from chaos. Within discussions of recursive complementarity, Sawada and Caley (1986) suggest children need the freedom to participate in building their social context and in helping to establish new communicative recursions. To do so, they speculate that a domain of self-creation for teachers and students is required, and they recognize this entails the process of autopoiesis. Here then the use of the living systems metaphor is directly connected with education.

New Metaphors For Education

Recognizing the opportunities offered by the living systems paradigm, new metaphors for education, and mathematics education in particular, are appropriate. What is needed is the explication of the living systems metaphor in both the social and cognitive domains of education.

> Living systems are organized . . . multi-leveled structures, each level consisting of subsystems which are wholes in regard to parts, but parts with respect to larger wholes . . . (there are) two tendencies: an integrative tendency to function as part of the whole and a self-assertive tendency to preserve individual autonomy. . . . In a healthy system there is a balance . . . consisting of a dynamic interplay between the two which makes a whole system open and flexible (Capra, 1982, p. 43).

Using such a metaphor within the educational context, children and teachers are seen as subsystems within the system called "classroom", which is itself a subsystem of the "school" or "educational community", and so on. Here, in the living systems metaphor, learners are both autonomous individuals and integrated participants of a whole such that the dynamic interplay between these roles is refereed by dialogue and mutual feedback.

The "living system" metaphor is further extended when each learner is viewed as a self-organizing, self-generating, autopoietic system. As Sawada and Caley (1985) suggest:

> communication is the vital process through which self-organization emerges and the system itself determines its own structure, its own size. Teachers as well as students will therefore be very sensitive listeners, this sensitivity encompassing all forms of expression, both verbal and non-verbal. . . .
>
> Auto-catalysis and cross-catalysis amongst teachers and students will become normal in this self-organizing system (p. 16).

Therefore, organization or grouping is not imposed upon the participants, but rather the "coming together" of subsystems is by choice. This does not necessarily exclude the impact of a teacher but rather as Gray (1981a) suggests:

> . . . the role of "the teacher", then, is to share experience and understanding in such a way so that what he/she says will become organizing foci for the self-oraganizing process in the other (p. 315).

The authoritarian role of the teacher or even the role of expert necessarily disappears as the teacher's role of facilitator and mediator comes to the foreground. In this sense, the teacher too is an autonomous member participating in the living system; the "teacher" is a learner.

Jantsch (1979) captured the self-generating character of a system in the following description:

> Learning would no longer be adaptation to specific form into which knowledge has been brought . . . but the formation of new

> and alive relationships with the multi-faceted reality which may be experienced in many forms - learning would become a creative game played with reality . . . creative processes would be permitted to unfold and form new structures (p. 284).

Thus creativity embedded in self-generation is essential to the metaphor but its actualization is dependent on the role of feedback between the members or learners. Positive feedback between learners in a non-hierarchial setting where ideas mutually and recursively affect others' ideas leads to a form of knowing. In this metaphor, learners interact on an equal basis and often serve as precursors, i.e. supplying initial kicks (in sensu Maruyama,1963), for one another. Knowing that living systems are FFE, it is recognized that small kicks or minor differences between the interacting components can lead to quantum leaps in the system's evolution whether the system be an individual child or a group of children. Such is the case of systeming within therapy groups described by Gray (1981b):

> As the exchanges continue, there is considerable fluctuation because each member's input is similar to, but not identical with, the original one. For this reason, members are able to exert mutual influence on one another. They are "systeming". And the result is that an emotional theme develops and transformations begin to occur. . . . Once the theme is well established and transformations have taken place, the therapist waits to give members time to reorder their internal dynamic interaction (p. 205).

Thus we see that information is not only exchanged or transferred, but more importantly, is produced by the system. Thus learners not only "share" the learning experience, but "create" it as well.

The autopoietic dimension of the system concerns the self-reflection and recursive activity needed to transform one's immediate reality and renew oneself. When dealing with multiple learners who are each autopoietic and who in turn interact in an autopoietic system, non-linearity is inevitable. Determinism is lost. Not only do children renew themselves but in doing so, renew the group or social context to which they belong. The classroom therefore needs be a FFE context in which learners may maintain interactions and communication so that both personal autopoiesis and social autopoiesis flourishes.

The living systems metaphor thereby casts mathematics learning in a dynamic, active role. The mathematics environment is one in which the learner is a capable producer of knowledge and a builder of his/her own structure. The "learner" and the "learning environment" are "systems in co-evolution".

New Metaphors for Content

It is appropriate also that the mathematics curriculum be compatible to the living systems metaphor. Certainly mathematicians are familar with a mathematics which possesses the interrelatedness of a system and also possesses the ability to grow, to become. Mathematics, in general, is a creative discipline which is both divergent and indeterministic. Mathematics, as a human endeavor, is extremely conducive to a "living systems" metaphor.

The content or subject matter needs to be flexible enough to permit learners to twist and shape it into their own personal works of art. "Broad" topics of study should be such that the imagination, tenacity and ingenuity many problem solvers demonstrate in today's extracurricular situations be present within the educational context. To fulfill the metaphor, it is believed as Higginson (1973) indicates:

> that the learning of mathematics has to be seen in this way as individual creative (or recreative) acts taking place in a social context. . . . We believe in the value of the child's mathematics, that he should have the freedom to make it and to use it and talk about it (p. 119).

Hence, the mathematics content must not be preset or static; invention and inquiry are essential components of a "living" mathematical experience. As Bateson (1979) suggests :

> creative thought must always contain a random component. The exploratory process - the endless trial and error of mental progress - can achieve the new only by embarking upon pathways randomly presented - some of which when tried are somehow selected for something like survival. . . . (p. 182).

The mathematics content per se then will serve mostly as an activator for further exploration and organization, which in its own right is mathematical. Such mathematizing is supported by authors like Freudenthal (1973), Papert (1980) and Pritzkau (1975), the latter of whom describes it thus:

> . . . content is never settled, never final, never complete. Subjects can be produced every day, and the learners - both teachers and students - are the producers . . . one becomes aware of meanings as part of the process of being enroute to new and expanded areas of inquiry. . . . In viewing some of the primary effects of the surrounding phenomena as he opens up to them, he begins to order knowledge into some form of personal workable meaning (p. 41).

In summary, the mathematics curriculum itself must be spontaneously built. Mathematics must be seen as a human activity, as a method, a language, an art, a science and much more. Mathematics must be such that the learners are able to "live" it, and "own" it.

A Model For Mathematics Education

To capture the essences of the living systems metaphor within the present context of schooling, an appropriate model is that of a small enrichment group. A small number of learners - children of varied abilities and interests, as well as one adult - are brought together to form a small autopoietic community whose main focus is the exploration of enriched mathematical activities. Let us imagine, then, a mythical Mathland wherein all citizens are immersed in the learning of mathematical ideas. The enrichment lies both in the openness of the environment and the flexibility and challenge of the "content".

Dialogue with peers is the key driving force coupled with the "natural" desire of learners to make sense of their world. Ideas and projects are pursued for personal fulfillment, and sharing of those ideas is initiated by the learners themselves and are not required per se. Children choose the paths of "adventure" they wish to follow and the adult, while also participating, serves as a resource and a catalyst similar to the other learners in the system. A specific curriculum is not imposed; and temporal and spatial constraints are minimized.

As Papert (1980) suggested, there are "no constraints on exploration . . . the power of the environment is that it is 'discovery rich' " (p. 162). There is the attempt to permit each learner to taste mathematics in the making of independent creative work (Polya,1965,p.157). However, exploration and discovery are not held at the concrete level per se but rather, reflection and conscious awareness are encouraged so that learners might develop along several levels of thinking. As Donaldson (1978) indicates:

> awareness typically develops when something gives us pause and when consequently, instead of just acting, we stop to consider the possibilities of acting which are before us. The claim is that we heighten our awareness of what is actual by considering what is possible. . . . (p. 94).

Through ongoing dialogue, learners call into question the activities of the other or through errors enroute to a goal, a learner pauses to reflect on his/her own direction. It is with this reflexive, recursive activity that the adult may serve a key role, being a mediator for other learners and interacting with them as they each attempt to construct meaning from their experiences. As Feuerstein (1980) posits:

> . . . a fundamental process to emerge as a result of mediated transmission is the development of comparative behavior . . . . the need to link and relate objects and events is transmitted by the mediator to the child (pp. 34-35).

The overall atmosphere of the learning environment encourages a search for patterns, for order. Through their constructions, learners come to know specific mathematical concepts, as well as the human activity of mathematizing. Members of the community serve as initiators, supporters, critics, admirers, friends, foes and overall, fellow learners. They are each autopoietic wholes in their own right, but also parts of the whole - the autopoietic community. Both the group and each individual are far from equilibrium, and sensitive to fluctuations, even "silent" ones, which are ongoing throughout such a dynamic process.

Hence this model mathematics learning environment actualizes the living systems metaphor. Its structure and evolution is autonomously determined by the participants themselves. Its boundaries are generated by the group members and thus coherence and unity depend on and are constructed upon the relations between and interactions of the learners involved. The children and teacher generate both the context and the content. Such a group would necessarily be heterogeneous, non-hierarchial and include mutual causal processes. The system would be "alive" in that the system would be far from equilibrium and each member would constitute its production.

Appropriate Mathematics To Be Used

In such a model of mathematics education, the subject matter itself must be conducive to the "living systems" metaphor. As shown earlier, for mathematicians, mathematics is profoundly personal and extremely flexible. Such a mathematics is needed here so that ideas can " . . . be born in the students' minds and the teacher should act as the midwife" (Polya, 1965, p. 103). To allow a variety of adventures, to allow individual invention and to allow free exchange of ideas, the mathematics must not be narrow, nor specifically rule bound. Many mathematical topics or branches fully qualify, except the "traditional" algorithmic curriculum. There is an unlimited supply of "seeds" or "kernal activators" available in mathematics. Papert (1980) chose LOGO and turtle graphics for his model; Higginson (1973) chose polytopes and poliminoes for his; Sawada and Caley (1985) chose LOGO projects for theirs. The extremely rich content of mathematics that evolved since Euclidean geometry provides an array of ideas available for study.

Geometry has been chosen as the focus for the present study. Throughout history it has pervaded all of mathematics. As Freudenthal (1973) suggests: "Geometry is one of the best opportunities that exists to learn how to mathematize reality. It is an opportunity to make discoveries. . . . ." (p. 407). In particular, with respect to this model of mathematics learning, geometry is intended to focus on relations, intuition and qualitative experiences. If children are to appreciate mathematics as a whole - then we must resist the temptation to quantify only and to make the content rigid. As reported by Wirzup (1976) :

> Piaget asserts that traditional geometry instructions begins too late and then takes up the concept of measurement right away, thus omitting the qualitative phase of transforming spatial operations into logical ones. . . . (p. 16).

In this model, it is the "qualitative phase" as described above which is of utmost importance.

<u>Dissection Motion Geometry</u>

Such qualitative mathematics is strongly apparent in dissection motion geometry (DMG), a term coined by Rahim and Sawada (1986). DMG deals with piece-wise congruency and the "invariance" of area under "subdivision" and changed position transformations. This means that if a shape can be subdivided into smaller pieces, which when rearranged form a second shape, the two shapes are piece-wise congruent, and the area covered by each shape is the same. It is a geometry with vast potential that incorporates paper folding, paper cutting, and transforming of pieces of paper to create new shapes. It is open to much experimentation and the mathematical concepts embodied in such activities are numerous.

From such activity, children engage in valuable spatial work; they are exposed to the "conservation of area"; they can be involved in shape recognition and naming; they become intuitively aware of interrelations between shapes and they learn of midpoints, perpendicularity and diagonality. There is opportunity to make generalizations from patterns which will evolve as well as an opportunity for creative work with shapes. Such hobbies as origami, stained-glass art, patch quilting can be connected with or emerge from dissection activity. Children could, if they wished, even use dissection geometry to discover or develop or prove "traditional" formulae and algorithms. The Pythagorian theorem, for instance, can be proved via dissection theory; area formulae can be uncovered via dissection theory, and so on. Dissection theory can apply in both two-dimensional and three-dimensional space, although in the latter volume is not always invariant (Rahim and Sawada, 1986).

Dissection motion geometry which is tied strongly to concrete manipulation, permits children to "own" it and make it "theirs". It is unlike the "foreign" deductive geometry of high school and the "foreign" definitions of Euclidean points, lines, rays and so on. A child begins with a shape - a rectangular or triangular piece of paper, for instance - and by folding, cutting, turning, sliding or flipping, reconstructs another shape; the resultant can be unexpected or aimed for. Both experiences have high value. As Lesh (1976) stated: " . . . by attempting to isolate the mathematical essence of concrete situations, youngsters begin to appreciate the real beauty and power of mathematical modeling" (p. 204).

Dissection motion geometry is closely linked to the child's reality. His paper plane constructions, the "transformers" he plays with, and the visual decisions regarding shapes and shares, all contain aspects of dissection theory. The power of dissection motion geometry lies in the fact that any collection of visual properties tends to invite the learner to organize them which then leads to logical ordering, or deduction. It does not have to be imposed. Children will build structures; we only need to help them make those intuitive, often unconscious thoughts conscious. Dissection motion geometry provides an opportunity for educators to tap the 'natural' capacity of human beings in general, and children in particular, to engage in active invention as well as to seek flexible responses.

The breadth and depth possible with topics in dissection theory makes it highly conducive for actualizing the "living systems" mataphor of education. It is an open , dynamic subject matter, comparable to the openness of the environment in which it is met. Likewise, DMG is a part-whole configuration similar to the systems theory itself and thereby embodies an "organization" isomorphic to a living system. Its openness and flexibility is very conducive to the coupling of child/DMG or children/DMG wherein such systems can be self-generative. Learners - the children and adult - are apt to be amazed and enthused at the divergent, yet interrelated paths they might follow.

Support for Actualization of Such A Model

Maturana and Varela (1980) indicate that "if their characterization of living systems is adequate, then living systems should be possible to make at will. Therefore, an actualization of the living systems model previously described is both appropriate and necessary to ascertain its true potential. As they indicate, "given the proper components and the proper concantenation of their interactions, the system is realized" (p.95). Thus, given learners and the proper opportunities for them to interact, a living system should actualize. As Prigogine and Stengers (1984) point out, "governing the development" of a system "determined by multiple interacting elements" is difficult and quite "unanticipated changes may result" (p.203). Doll (1986) agrees that "any curriculum which emphasizes the active and the reflective - the only way to achieve internality - must by nature run the risk of disequilibrium" (p.15). However, such 'adventurous developments' and 'spontaneous reordering' is conducive with the living systems metaphor.

Researchers and theorists in other curriculum areas, indirectly, support the implementation of the "living systems model". Holdaway (1979), when addressing the teaching of reading and writing, advises:

> . . . Any approach to literacy must allow the individual learners to pick their own way - always in the company of guiding and sustaining friends (p. 191).

Certainly this must also be true of the needed approach to mathematics learning. Considerable faith in the learner as an "autopoietic system" is drawn from the known experiences of the young learner, the pre-school child. Young children are quite capable of learning to talk , walk and much more, many years before they ever enter a "formal learning institution". As Donaldson (1978) aptly states, " we do not just sit and wait for the world to impinge on us, we try actively to interpret it, to make sense of it. We grapple with it, we construe it intellectually, we represent it to ourselves" (p. 68). As learners we are not "naturally" passive but on the contrary,from the earliest days we are active theory builders seeking to explain our world , and our relations in it. Therefore, from the belief that all children and adults are fundamentally autonomous learners and from the belief in the emergence of dissipative structures, the researcher proposed that the actualization of a living systems model for the learning of mathematics was a viable alternative .

Living Systems Research : Its Description ?

Before discussing the actualization of the proposed model, the role of the dissertation within a "living systems" paradigm requires consideration. As Sawada and Pothier (1986) indicated "living systems are neither deductive nor linear; only our linguistic descriptions sometimes suffer in this way" (p.6). It is this difference between the "reporting" and "living" of an experience that warrants the writer to alert the reader to "inconsistencies" between the "experience" and its "description". Within the data analysis, for instance, the individual development is discussed separately from the group development; yet, during the "research experience" these were inseparable events which could not and were not detected as happening after or before the other. The printed transcripts also portray an "incomplete picture" of the conversations they describe. No dialogue throughout the whole experience possessed the linear characteristics the structure of the transcripts imply. Speakers seldom spoke in turn, or waited for others to complete their thoughts; the conversations within groups evolved simultaneously rather than prior to other conversations per se. As in "every day" group dialogue, speakers interrupted one another, carried on multiple conversations at once, and engaged in other activities as well.

Another shortcoming of "description" versus "experience", is the difficulty in relating "tacit" knowledge and "feelings" embedded in the events as they unfolded. Even though I might capture and describe the "tangible" behaviours through which feelings or beliefs might be exhibited, those feelings and beliefs must not be equated with the behaviour. As "love is more than a hug", feelings like "group coherence" were more than "saying encouraging words in support of one another". To enhance the descriptions then, the reader must become an active participant and must try to "live" the described experience in order to "extract" as much of the "reality" as possible.

Consequently, the reader is invited to couple with the writer (through my dissertation) in an autopoietic manner. I wish reader and writer to dialogue with each other, even though, due to the restrictions of print, I am unable to respond spontaneously to and mutually interact with you. The document alone should serve as a precursor for the reader; a perturbation which might lead to conversations with him/herself or with colleagues. Through this coupling of reader /dissertation, it is hoped that the research experience continue to be a "trigger" for the generation of yet more ideas. The writer wishes to do more than pass on information, but instead through both what is said and what is unsaid, she intends to preserve the "life" of the actualized system through this perturbation. Comments which are made are done so in the spirit of "initial kicks" which "hang in the atmosphere" of the reader/(writer)dissertation system and whose pursuit depends on the autopoiesis of that very system.

Rather than separating the researcher from that which is researched as is attempted in the "Newtonian" paradigm, in a "systems" paradigm, they are seen as a unity. Therefore, the reports and descriptions of systems research are necessarily part of that research unity, also. As such, the dissertation itself was one part of the whole experience, without which certain insights would not have emerged. This document which began as a conversation with the data has evolved into a conversation with the reader. Just as the videotapes and diaries provided a lens through which the researcher was able to view the "experience" on a different level from the "actual events", so too the data analysis and written discussions provided yet another visit. All of these "visits" intertwined to form the "whole" of the research experience. To grasp that whole - its spirit, its evolution, its relations, and its events - membership is necessary. The best that can now be offered to the reader is the sharing of thoughts, perceptions and descriptions as mirrors, through which he/she might encounter the "research experience". As Sawada and Olson (1986) aptly stated :

> . . . Separating objects from the whole would be seen as an analytical act done by an observer; not as the reality of the objects. In fact . . . identifying objects at all is purely a descriptive act. . . . descriptions need not destroy the unity. Indeed, descriptions may help uncover the phenomenon at a deeper level . . . But this will only happen in a deliberate way if we are aware that our analyses are creations of the human mind, nothing more . . . (p.4)

To remain true to the "systems paradigm" in which this disssertation is couched, I do not wish the conversation to end here. I do not wish the reader to see what I saw only; to view this report as a completed entity. Instead, at this juncture, I invite the reader to view this description as a perturbation, a catalyst; a beginning for the future rather than a summary of the past.

CHAPTER III

METHODS

Research Plans

To be true to the systemic metaphor, and in order to actualize the model for mathematics learning and follow its evolution, the current study remained open-ended with a priority on spontaneity. Both the outcomes of the study and the process of research itself was unpredictable from the initial conditions.

The researcher - as participant in the living system - exercised her autonomous living structure. As Durkin (1981b) suggested:

> The working relationship between the scientific knower and that which permits itself to be known inevitably becomes a two-way street with the autonomous researcher engaged in a cooperative effort at self-description and self-transformation with the equally autonomous system under investigation . . . . the investigator and the investigated are mutually responsible for each other (p. 29).

The children and the researcher were collaborators throughout the experience, especially with respect to the learning of mathematics within the living systems model. The interrelationships and processes of the production of these relations were emphasized in that process overrode content and the dynamics of the events - the interplay between an individual and the group, an individual and the material, the group and the material or an individual and another individual - overshadowed specific material products and subject matter. As in current biology, the individual was not dispensable for the benefit of the group (Maturana and Varela, 1980, p.118).

The Role of the Researcher

As the "adult" member of the "system", the researcher's initial function was to "catalyze, facilitate or stimulate the system's potential capacities" while a secondary function was to "regulate the exchanges among the members until they develop their own steady states and have achieved autonomy" (Durkin, 1981a, pp.19, 23). As the living system evolved the researcher became yet another "equal" member of the group, with a comparable role to other learners in the system. At this point both the researcher and other participants played key roles in determining the generation of the processes and relations which emerged. As Varela (1979) indicated:

> . . . In the characterization of organizational closure, nothing prevents the observer himself from being part of the process by specifying the system, not only in describing it but by being one link in the network of the process that defines the system. The situation is peculiar in that the describer cannot step outside of the unity to consider its boundaries and environment simultaneously, but it is associated with the unit's functioning always as a determining component. Such situations, to which most of the autonomous social systems belong, are characterized by a dynamics in which the very description of the system makes the system different. At each stage, the observer relates to the system through an understanding which modifies his relationship to the system . . .(p. 57).

As an active participant in the "living systems model", the researcher behaved as an autopoietic system involved in a mutual causal paradigm with other autopoietic systems, namely the children. A conscious effort was made to shed the "traditional" role of the "teacher".

Actualizing the Enrichment Group

When considering the "creation" of the "enrichment group" within the "living systems metaphor", Gray's (1981a) "general system precursor formation theory" provided insight into how one might begin. He defined the key ingredients as:

> 1. system precursors . . . entities which have a capacity for forming an ongoing system when two or more are brought together in a relational sense.
> 2. system formation . . . the anamorphic process that results in the production of an ongoing system.
> 3. system block . . . processes that either prevent system

> formation or return (it) to the precursor state.
> 4. system precursor activation - usually accomplished by an organizing force, a catalytic agent or an initiator.
> 5. system-forming space - a protective space of relational, rather than geometric type, around organizing forces and precursors that provides a necessary degree of isolation for system forming to take place (pp. 302-303).

This theory also coincides with Varela's (1979) notions that to establish autopoietic dynamics it is not the molecules or components which are important but rather the relations which these molecules or components satisfy (p. 27).

In this study, the precursors (components) were six grade four pupils, three boys and three girls, of varying abilities. The choice of the boys was greatly influenced by the classroom teacher's opinions whereas the choice of the girls was a more random one. Two of the boys were considered "early finishers" in mathematics and thereby caused complications for the regular teacher; the other boy, who in the researcher's opinion openly asserted his autonomy, was labelled as learning disabled and was considered a behavior problem. One of the girls chosen was considered bright by the teacher, while the other two were considered average. All three girls were fairly quiet and obedient during regular classes and thereby provided a contrast to the boys. The researcher also tried to choose children whom she had seen working together or chatting in a friendly manner. The researcher briefly described her planned "enrichment group" to the children and gave each of them the option to refuse to participate. Indeed, one of the initial six did not want to participate and was then replaced by another. Parental consent was also requested and obtained.

The dissection motion geometry described earlier was to be the "mathematical" precursor. Children were given a broad description of the topic in terms of "paper folding". The parameters involved the folding of one shape to cut into parts which would then be taped to form another shape. As the system evolved however, individual preferences of the children in actualizing dissection motion geometry overrode the researcher's desires to have them follow a "program".

The relational time/space, consciously created by the researcher, was such that all members of the system participated in a non-evaluative, collaborative environment. There was no testing involved; neither was there a strict scheldule for completion of activities. Participants were free to choose the materials they needed and when they needed them. The physical space itself was away from the regular classroom but within view in the same open area of the school. The atmosphere was such that children could speak out when they desired and they could choose to whom they spoke and about what. Hand-raising, for example, was not required or encouraged. Movement was not restricted within the topological space of the group although they usually requested permission to leave the area. At no time were rules overtly laid out, but rather the participants themselves generated them over time.

In the initial phases of the study, the researcher attempted to develop a rapport with the children. Concurrently, attempts were made to "mediate" the mathematical experiences with the intent to bring the mathematical precursors into the topological space. As time passed, the researcher became more and more involved in the mathematical activities on a mutual basis, thereby doing and talking mathematics similar to other participants. Researcher as participant differed from researcher as teacher in that in the former role, children interacted with the researcher on a more reciprocal basis whereby they helped her with difficulties as well as other children. In the latter role, children often requested help from the researcher but did not offer it.

Spontaneity and Recursion

Spontaneity was present in many respects, including the researchers "reaction" during a particular episode. However, such spontaneity was tempered by the reflections of the researcher after viewing the daily video tapes of the sessions. By reviewing the video tapes and notes collected daily, the researcher made conscious decisions to try certain activities or pursue certain ideas on a following day in an attempt to provide perturbations or to accommodate unexpected perturbations which arose. Therefore, the reflections were to inform the researcher's actions within the "closed system". It was an attempt to step outside the boundaries and view the environment simultaneously. Spontaneity was not crushed by such "intentions" however for the "nature of the system" was such that when the researcher was totally involved as a participant, immediate interactions and perturbations were dealt with then and there, often without much thought. Spontaneity was also present in the other participants' actions; children often decided "on the spot" what they were to do or how they might proceed. At all times however this spontaneity was tempered by the mutual interactions of the other group members and the material itself.

Data Collection

As alluded to earlier, since the researcher was a participant in the "enrichment group", video tapes were used to capture the dialogue and the actions of all involved. These tapes were viewed daily by the researcher and particular episodes were highlighted and dialogue from these were transcribed. Particular evidence of "living systems" metaphor was sought and its presence or absence informed the researcher's actions in upcoming days. Diaries of "reflections", "methods" and "syteming" were also maintained on a daily basis. These diaries contained the researcher's thoughts with respect to her feelings of the past experiences and her intentions for future experiences. Notes were made of influences on the researcher's decisions as well as her behavior. Comments with respect to influences and interactions within the group were also made in diary form. At times these entries were made prior to viewing the video tapes; although other entries were made afterwards.

Once the study began in the cooperating school, other perspectives besides the actualization of the living system were added. Due to the openness of the cooperating principal and teachers as well as the physical openness of the classroom area, the researcher was given the opportunity to participate in two other roles. Observations of the children in their regular studies was permitted and the researcher maintained field notes of the observations she made while sitting at the back of the designated classroom or while viewing the classes from a distant spot within the area. Once again these observations did not detail every action or interaction, but were selective, in terms of the "living systems metaphor". Likewise, the researcher was also given the opportunity to "tutor" her six subjects in a small group. The tutorials were initiated in order to help children maintain their regular studies which were being missed while they attended my "enrichment group". These sessions were also videotaped and later transcribed.

The time-line for the study involved daily afternoon visits (from 12:30 p.m. to 4 p.m. on average) to the school beginning late September and continuing until late November. Toward the end of the study a second "enrichment group" was chosen but due to time restraints only one session was held. This session thereby turned into an "informal" dialogue with children who were interested in the "group's" activities. Three school days following the last session, the researcher returned to the school to interview the cooperating teachers and the "original" six children. Two separate interviews were held; one with the two teachers present and one with the six children present. The main purpose for such interviews was to ascertain the participant's perceptions of the experiences of the past months. A more detailed description of the evolution of the research design follows in the next chapter.

Data Analysis

The transcripts of the video taped sessions, the field notes pertaining to the observations of the regular classroom activities as well as the research diaries were used as the data. Video taped episodes were revisited only when clarification or elaboration was warranted. Samples of the six children's enrichment projects, as well as samples of the assigned tasks used in the other settings were utilized to enable thorough examination of the events. Throughout the analysis, the researcher was informed by the fact that she had been a participant within the "system" she now sought to view from an "outside" vantage point.

Initially, the data was examined for illustrations of dissipative structure within the observed contexts. Following this, the data was analysed more specifically with respect to "autopoiesis" in an attempt to determine its significance within the three settings studied. Overall, the analysis of data entailed an in-depth, recursive search of the specific interactions as well as the general atmosphere present in the research contexts.

CHAPTER IV

THE DESIGN OF THE STUDY

An Emerging Research Design

The structure of this study emerged spontaneously from discussions and negotiations (exchanges of information) with the participants of the research project. Initially, the researcher sought access to a small group of children with whom she might actualize the "living systems metaphor" under the guise of an enrichment project. The openness of the endogenous research design permitted the researcher to grasp other opportunities which presented themselves in this particular school context. The researcher/research system tended toward self-generation and developed a higher coherence as these opportunities led to three distinct settings from which valuable data could be collected. This development itself is a vital part of the story.

Although not overtly evident from the diary excerpts, this evolution occurred in a recursive fashion. Discussions with the school contacts as well as others in the researcher's world were occurring concurrently. Thus, choices were influenced by both the potential of the school milieu as well as the potential of the researcher/research system. As indicated below, my initial request of the school was to work with some children in an enrichment mathematics setting. Even at this intial contact, the school principal (P) provided valuable perturbations for the researcher/research system.

> Sept. 6, Friday
> First contact with school, spoke to principal over the phone.
> P: When do you want to see them - how often?
> TR: Two to three times a week ~~at least.~~
> P: How long, each session?
> TR: What are your times like?
> :
> P: One grade or a variety?
> TR: It doesn't really matter; what's convenient for the school?
> P: We work in open area - is that suitable, that is , a corner of

it or do you need a closed area?
TR: No, open is fine.

I also indicated at this time that I would like children of varied abilities and not just the "gifted".

The "open" concept was a variable not considered earlier but one which now actualized a higher range of permeability of the boundaries defining the host and research systems. The researcher would now have visual and auditory access to the classroom while she was also involved with her enrichment group. Plus the open concept provided flexibility of the children's movement to and from each setting. The next meeting with the school principal and the prospective cooperating teacher proved to be a source of other paths the researcher might consider. As can be seen from the following excerpt the participants in the research interacted on a collegial basis where all involved had the opportunity to suggest alternatives.

Sept. 17, Tuesday
First visit to meet the principal.
. . . she asked me if I was more clear about what I wanted.
I suggested my ideal : To meet with 5 children every day for an hour or so, until December.
. . . (Discuss other ideas) . . .
She informed me she had spoken to the grade 4 teacher . . . she seemed interested in my project.
We pursued possibilities.

P: . . . a lunch hour group, this would not interfere with studies. Would it be interesting so children would volunteer?
TR: . . . what about taking them from a variety of classes to balance the loss? . . .

I indicated I would be willing to help the teacher with the children if they fell behind.
P: Would I be interested in team-teaching . . .
At 3:30 I met with the teacher; we talked about scheldule. . . .
T1: . . . work with small group on my own project every day, then tutor them Tuesdays and Thursdays on work missed.
TR: . . . I would like to see them in regular math. class . . . maybe I could tutor in this context, . . .
Team teaching was brought up again, . . . Alternate lessons with her. . . .
T1: . . . maybe a math. center, if it didn't have to be same 5 children. You could choose the enrichment materials-

worksheets- for early finishers.

At this "major" bifurcation point, the choice was made to set up a small enrichment group of six grade 4 children (three boys, B1,B2,B3; three girls, G1,G2,G3) who would work with me every day for one-half hour and who I would tutor for one hour a week in an attempt to make up for classes they would miss while attending the enrichment project. Other suggested options were left open as later alternatives. When some early observations of the regular classroom setting showed potential for valuable data, and since the openness of the physical environment itself permitted continual observations, a dialogue with a committee member was sufficient to cause the researcher to include observations of the "host" group as yet another aspect of the study. Hence, I requested that I use my "off" times to observe the subgroup of children and their peers in their regular classes. The excerpt below describes the procedure adopted at this time.

Oct. 8, Tuesday

Observe social studies class during first period. Meet my small group during next period and we do geometry. After recess, I meet them for "regular curriculum". . . . They work on exercises assigned to class during week.

Children frequently voiced their displeasure with the number of "required" exercises they had to complete in the "catch-up" sessions or do for homework. During the third tutorial, a discussion with three of the children prompted a further spontaneous alteration to the make-up of these sessions.

Oct. 8, Tuesday

They worked on 4 ditto sheets of exercises.

B1: I hate this so much I could die.
TR: NO!

B3: I hate it, too.
TR: Why?
B3: It's so boring. I know how to do it.
G1: Why so many?
TR: If you do well on the test, I might ask T1 if I could do it differently with you.
B1: Why do we have to do them all?

:

Consequently, with the cooperation of the regular classroom teacher, the researcher was permitted to adopt a more active role during the tutorial. When the new chapter was to begin, the researcher took on the responsibility for both the assignment and the "teaching" of the regular curriculum for this small group. As a result the "catch-up" sessions were dissolved and replaced by a "regular" small group instructional setting.

Simultaneously, the regular classroom itself was undergoing change. With the introduction of an "intern" to the school, the regular grade 4 class would be split and the intern (T2) would teach social studies while the regular classroom teacher (T1) taught mathematics. This provided the opportunity for the researcher to continue to observe her subjects and their peers in regular classroom settings as well as monitoring, from a distance, the activities of other children in the regular mathematics class. Since there was only one other teacher, the music teacher (T3), who taught the grade 4 children, I also gained access to her classes for observational purposes. Hence, the observations of the regular classroom included three teachers- T1, T2, and T3- teaching the subjects of science, mathematics, French, social studies, and music.

By October 15, the design had evolved to the point where the researcher was an active player in "two" settings and a "passive observer" in a third. Thus, the design - the structure- of this study emerged from "the interaction of a given system with its surroundings" (Prigogine, 1984, p12). The three contexts which evolved - the regular classroom (S1), the "regular" small group (S2), and the "enrichment" small group (S3) -- provided three distinct settings within which the researcher could observe and/or participate in the actualization of the living systems metaphor.

As indicated at the outset, the physical space in which the research took place was also of particular significance. The grade 4 class was situated in an open area of the school shared by the grades 5/6 class, the library, and a pre-school/ after-school care group. Of particular relevance to this study was the open area which the grade 4 class shared with T2 and his social studies group and the researcher (TR) with her enrichment group. As Figure 1 illustrates, the physical space was such that all three groups were within viewing and hearing distance of one another. Thus the researcher, children and other teachers could be at all times semi-aware of the activities in the other settings while simultaneously working in their own groups. This high permeability of subsystem boundaries also had the potential to influence children's and teachers' movements to and from classes in a different manner than if distinct rooms were involved.

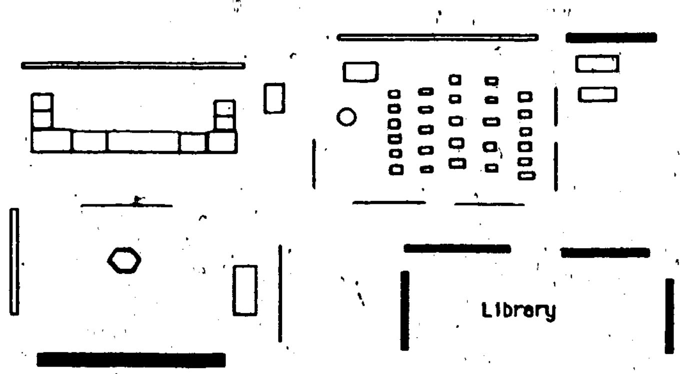


Figure 1: Floor Plan of Open Area Classroom

Experimental Contexts

Even though the three contexts were not designed as experimental treatments, their emergence provided such a potential. To appreciate the milieu of each setting, a general description is warranted.

Enrichment Small Group (S3) Context

The physical space for the "enrichment group" entailed a hexagonal table with seven chairs, as well as a "librarian's desk" on the side. Children chose where to sit and the initial pattern was that of three girls , a space, three boys and me. Later, two boys situated themselves at either end of the librarian's desk. Children stood or sat whichever was comfortable for them and the area itself was at their disposal. The researcher either sat at the table with the children and worked on the activities herself or helped the children directly.

Regular Small Group (S2) Context

In the "regular" small group, the children often chose to sit in a somewhat circular formation on the floor. On other occasions we sat at the hexagonal table, and on one occasion the children sat at chairs in the social studies area. Only in the latter occasion did the teacher stand at front of the children; otherwise the researcher sat with them. There was also one session, involving measurement activities, where children moved freely about the space in general. Overall, much of the activity in this setting was oral or active in nature, utilizing manipulatives and games.

Regular Classroom (S1) Context

The "regular classroom" setting differed according to the subject being taught. The mathematics, French, science, and early social studies classes were held in the classroom area where seats were arranged in rows. Children were assigned to their seats and even when numbers decreased, children usually remained in their own desks. There were tables at the back and to the side that were also used at times for group work. The teacher's desk was at the front to one side and the teacher spent much of the time at the front near the chalkboard. The social studies classes taught by T2 were held in a separate area to the side where a U-formation of tables and desks had been arranged facing the chalkboard. The children were assigned seats in alphabetical order. In Music, children sat on successive steps of a raised platform in the music room with one line of girls and one line of boys. Children chose their particular spots to sit however. Once again the teacher stood at the front or sat at the piano which was also at the front of the room.

Teacher Roles

In all three contexts the teacher provided directions and/or instructions as well as being the "checker" for the correct answers. This role, although present in the "enrichment group", was not as prevalent as it was in the other two settings and it was more dominant early in the development of the group rather than at later stages. The teacher as participant was a role exercised mainly by the researcher in the S3 setting whereby she too, as well as the children, carried out the activites. Such participation was also observed in the Music classes since the teacher often sang along with the children. This was not observed in the "regular classroom" in that here the teacher illustrated with examples but once the work was assigned, the teachers did not also carry out the tasks. The teacher as authority was also present in all three contexts, especially with respect to the children's behavior. However, the use of this authority varied, with its more frequent use in the regular classroom setting and its less frequent use in the enrichment context.

Children's Roles

In the various settings, the children's roles ranged from "follower" to "creator". In the regular classroom (S1) there were some occasions whereby children did create their own stories, but often they followed restrictions set down by the teacher. In the regular small group (S2) there was some opportunity for children's ideas but often they were to complete preset exercises or games. In the enrichment small group (S3) more of the children's ideas were utilized. A detailed look at the curriculum in these settings might aid in understanding the roles of teacher/ child in the three contexts.

Curriculum Within Each Context

In the S1 and S2 settings, a predetermined curriculum was used and the major control of classroom events belonged to the teacher. The textbook was a major influence for the teachers in the "regular classroom" in that when a chapter was completed, a test followed, and then the next chapter was presented in much the same manner as the earlier one. Exercises and assignments were given from text materials or worksheets. One project, which I referred to as "Hallowe'en skits", did emerge spontaneously from an informal discussion of a scheduled party. As illustrated in the excerpt below, the routine of the week was altered to accommodate the creation, development and practice of skits during class time.

> Oct. 21, Monday
> At about 3:20 T1 asks if they want to discuss their Hallowe'en party. They get excited and talk at once. T1 directs those with ideas to raise their hands. They get noisy again as suggestions start coming. . . . At 3:26 or so she gives up; she's frustrated by the noise.

> Oct. 23, Wednesday
> . . . At recess many of the boys were over looking at the camera: B1 pretended to be a pop star while others viewed him in camera. . . . I mentioned to B1 that if they do skits at the Hallowe'en party maybe I'd video them and show them. . .

Oct. 28, Monday
Last period, T1 asks me about the video in front of the children. We decide I'll video their skits early in the afternoon. She gives them the period to work in groups on the skits. . . . T1 suggests to one group that they write it but they disagree. . . . B8 comes in to complain to T1 that his group is just running around. . . . T1 calls all of them back to their seats.

Oct. 29, Tuesday
. . . . She is letting them work on their skits. . . . The boys are here (in my area of the room) working on their skit. They're loud and it seems as if they're just running around. . . .
T1 is upset with the noise and threatens she'll cancel the party if they don't behave better tomorrow.

When the children presented their skits on October 31, it was evident that structure had emerged from the perceived chaos. In the "regular classroom" this re-ordering of the "usual" procedures was tolerated only because it was seen as a temporary disruption and as T1's comments indicated, class would return to "normal" following the holiday.

In the S2 setting, the researcher, in the role of teacher, sought alternative methods to replace the "routine exercises" of the textbook. These included the use of manipulative aids, games, and the active participation of the children in such activities as "problem posing" and "measuring". However, the agenda was still largely teacher-dependent and concepts were chosen from the regular curriculum, since the children in the small group were still required to take the chapter tests as usual. At times, in this context, spontaneous suggestions made by participants, like "let's play that game again", were overlooked in an attempt to "cover the required material before the test".

In the S3 setting, the interactions between the children and the researcher greatly influenced the projects which the participants pursued. Initial vague instructions concerning the dissection motion geometry (DMG) activities were honed to restrict the "paper" creations to two-dimensional figures, but otherwise the product and process were left to the discretion of the individuals, with the "fold and cut" technique being encouraged as much as possible. The intended DMG activities were carried out by some of the children but often personal preferences of shapes overrode this priority. Thus, the initial concerns, illustrated by the following excerpts, eventually gave way to children's desires and ideas of creating shapes with paper.

> Sept. 30, Monday
> TR: . . . Let's begin by taking one sheet of paper each and use it to make a shape. The only restriction is that I want you to use all the paper. . . .
>
> Oct 1, Tuesday
> B1: Now do we have to do certain things?
> TR: Yeah, I'm going to get a little more specific today because . . .
>
> B2: Do we have to do math. questions?
>
> TR: . . . What I want today, whatever we make today will always be flat.
> B3: Ohhh
> TR: The end product will not be folded. You may fold in order to do something . . . .
>
> Oct. 2, Wednesday
>
> TR: . . . so we're going to try something today. So, let's start; everybody take a (hand out sheets of paper) . Start this way.. . start this way . . . try not , don't cut it 'til I ask you to 'cause I'm going to give you little bit more specific directions today.
>
> TR: . . . First thing I want you to do is see if you can fold this paper in some way so you can get at least one square. . . .
>
> TR: . . . What I'd now like you to do is to fold it as many ways as you want, so when you cut different places . . . then I want you to be able to take two pieces and make it into a triangle.
>
> Oct. 3, Thursday
> As they begin, B2 asks for further directions so I remind him we're starting with a square (I fold paper as I speak) or rectangle and make another shape from it. . . .
> I suggest they treat it as a puzzle - once they've cut it, how can they put it back together? . . .

Oct. 10, Thursday

G2 has cut a square out but is still hesitant. I suggest she do anything she'd like. You've made so many (shapes), that's why you're running out of ideas.

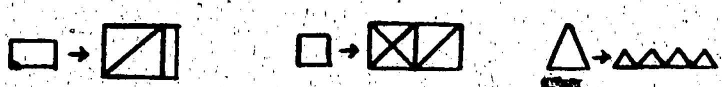
B1: I'm kinda getting bored with this.
B3: No, its fun.
B1: I want to try something different.

TR: O.K., what'd you like to try?
B1: I don't know. (continues with his shape)

In response to this pending bifurcation point, and still as an attempt to direct the children into DMG activites, the researcher casually introduced the concept of a "journey". Such a goal-directed activity was not imposed in an attempt to stay true to the "open structure" of the enrichment group.

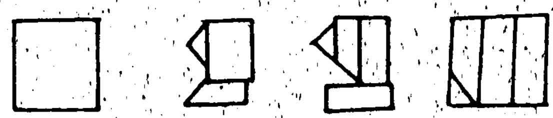
Oct. 15, Tuesday
Today I put forth two challenges. One was to do a journey - take a shape , change it to others , then back again. Two, take some shape and make as many other shapes from it.
B3: I'm still going to make 'funny' shapes.
TR: I'd like you to get away from funny shapes.

G2 . . . decides to make different shapes.



B2 pastes some triangles together. . . . G1 made a hexagon from a triangle . . .

B3 does a journey. (He doesn't tape it).



. . .B1 did a journey.(I did not see the intermediate figure, but he wrote "triangle-figure with 17 sides- triangle) ...

G1 completes a journey (i.e. square, trapezoid, square).

The "journey" activity was adopted by each child at different times during the following days. Two days after the first suggestion, B1 excitedly announced he was going to do "adventures" and by the end of this session they all had tried to complete at least one "journey".

The next spontaneous development in this setting was ignited on October 17 when I tried to encourage the children to think about displaying their journeys. The word display prompted B1 to suggest that we use Halloween shapes but my initial reaction was to disagree. However, other perturbations such as: B1 becoming defeated more readily than usual, B2 refusing to do much geometry and accusing the researcher of misleading him when he said "I thought we were going to fold . . . fold animals and stuff... " and G1 accidently creating a cat's face using DMG, led the researcher to re-introduce the option of making Hallowe'en figures on October 23. As a group we then proceeded to refine the project whereby we agreed to create a "mural" for the Hallowe'en party. The next alteration to my plans was influenced by a dialogue with my advsior who suggested using tangrams. Thus, after Hallowe'en, instead of insisting on a return to the "journey" theme, the group was also encouraged to try tangrams. They chose the latter and the curriculum now entailed solving tangram puzzles.

As this segment of the curriculum evolved, and the children had tried almost all of the available tangram cards, B2's question about how the originator had ever made the puzzles in the first place, led to the off-handed suggestion illustrated below, which later blossomed into our final major project.

> Nov.7,Thursday
> TR: Would you be interested in making your own cards?
> B3: Yeah, yeah, yeah!
> TR: Would you like to?
> G1: and cut the shapes?
> TR: You could, and make your own cards and challenge each other.
>
> :
>
> Nov. 13, Wednesday
> B3 reminds the researcher that they had planned to make their own tangrams.
>
> :
>
> TR: I thought once you've made a set . . . maybe we could get some in the other class to do them. Would you like that?
>
> :

Hence, in contrast to the predetermined curriculums administered in the other contexts, the curriculum of the "enrichment group" emerged as a series of projects.

<u>Settings as "Thermodynamic" States</u>

Once the three settings (S1, S2, S3) had emerged, it became increasingly apparent that they held the potential for illustrating systems "at equilibrium" (S1), "near equilibrium" (S2), and "far-from- equilibrium" (S3). Since the researcher could have a direct influence on two of the contexts, an attempt was made to consciously structure these two settings (S2 and S3) as embodiments of the "thermodynamic" states. However, because part of the agreement for accessing the enrichment group was that the six children maintain their regular studies, pressure of external standards was felt by the researcher both in terms of time and curriculum. Hence, the development of S2 deviated somewhat from the regular mathematics class but was still very similar to it. Thus partly by design and partly due to external conditions, S2 evolved as a near equilibrium setting. On the other hand, these external pressures were not felt in the "enrichment" setting. There were no tests to prepare the children for, nor was there an outside authority monitoring their "success". Thus the project had a free reign and was able to evolve more fully.

Emergence of a Quasi-Experimental Design

In retrospect, a more precise description of the emerging design is possible. Upon reexamination it is evident that a quasi-experimental design had emerged, even though a conscious effort was made by the researcher to avoid "traditional experimental designs". As the study unfolded, three treatment groups and a control group were discerned within the three settings. Thus data was available on four experimental groups.

Since the researcher observed grade 4 children in their regular classes, a control group representing the "normal" classroom experience was available. From this broader group, a subset of six children were exposed to three experimental treatments which the other children did not, for the most part, access. In the first treatment group, the six children were observed during their regular lessons in subjects other than mathematics. At this time, the subgroup was a part of the larger control group. In the second treatment group, the same six children joined the researcher for tutorial sessions on the regular mathematics curriculum. In the third treatment group, the same six children and the researcher explored DMG in a small group setting. Figure 2 presents the design in the Campbell and Stanley (1969) code where an X represents "the exposure of a group to an experimental variable or event" . . . and O refers to "some process of observation or measurement" (p. 6). As with Campbell and Stanley (1969) the "left to right dimension indicates temporal order and Xs and Os vertical to each other are simultaneous" (p.6).

Such a design lends itself well to comparative analysis of the events which were observed in the various settings.

	Design		Setting	
Control Group	{ X_0	O	AE	(S1a)
Treatment Groups	X_1	O	AE	(S1b)
	X_2	O	NE	(S2)
	X_3	O	FFE	(S3)

Figure 2 : The Emergent Quasi-Experimental Design

Experimental Contexts as Dissipative Structures

Since the initial intent of the research had been to actualize an "enrichment group" with "far from equilibrium" characteristics, it is relevant to determine if such a setting developed. Likewise, since the design provided data on the other available contexts, it is also pertinent to examine these settings for their status with respect to at, near or far-from, equilibrium states. To carry out such an exploration, insights were drawn from Prigogine and Stengers (1984) who indicate

> A system far from equilbrium may be described as organized not because it realizes a plan alien to elementary activities or transcending them but on the contrary because the amplification of a microscopic fluctuation occurring at the right moment resulted in favoring one reaction path over a number of other equally possible paths. Under certain circumstances, therefore, the role played by individual behavior can be decisive. More generally, the overall behavior cannot in general be taken as dominating in any way the elementary processes constituting it. Self-organization processes in far from equilibrium conditions correspond to a delicate interplay between chance and necessity, between

> fluctuations and deterministic laws. We expect that near bifurcation, fluctuations or random events would play an important role while between bifurcations, deterministic aspects become dominant . . . (p. 176).

Therefore, to establish the presence or absence of dissipative structures in the data, the deviations between the three contexts are reviewed.

S1a and S1b - At Equilibrium

The majority of observations in the regular classroom setting were made of the social studies classes in which the six children participated with their peers. Only the later mathematics sessions which were observed from a distance in a cursory manner did not involve the six children. Rather than separate the data collected in these sessions into S1a and S1b groupings, statements made by members of the enrichment group are italicized. When necessary and practicable, these groupings are differentiated in the discussion.

In general, the teachers, in S1, utilized prescribed materials to teach the subject area. The children sat in individual desks for most activities, although during science experiments they worked in small groups in various areas around the classroom. Sequences suggested in the textbooks were usually followed closely and worksheets and exercises were a large component of the students' daily workload. The child's input seldom altered the planned sequence and diversions were often checked immediately and were seldom followed up.

Sept. 24, Tuesday

Mathematics . . . Parking (is the title) . . . (exercises) # 1-15

T1 has a box of Dienes blocks . . . Children say they've worked with them before. T1 explains the relation between the blocks, then asks children to tell her. . . . .
B3: Boring, boring.

When reviewing a sum, . . .
T1: Who thinks they might not have it right; who's confused?

(Children give answers and are asked to think aloud)

B4: This is boring.
Another child: But you have to do it, B4.
T1 assigns two sums written on the board.

T1 (tries to check the boys who repeatedly say it's easy): There may be some who might be weaker . . .

Sept. 30, Monday

Social studies . . . T1 had read about legends and is about to assign questions.
B3: We only have three minutes.
T1: Please copy the questions, we have time for that.

Questions raised about the page number . . . leads to realization that the page was in T1's book . . .
B9: Why don't you give us the page?
T1: It's good for you to copy.
B4: It's more boring.

Individual students who refused to follow the agenda were often isolated either physically or verbally from the class in general.

Oct.3, Thursday (S1b)

T1: 'Are there any questions. No, well, we've already discussed it. Do your own story quietly! Use two periods to write.

I just noticed that B3 has been sent out, he's sitting in the library . . . a few minutes pass and B3 takes the initiative to return . . .
B2 is working at a cubicle just to the side. It's away from the immediate class but still in "classroom territory".

Children were usually instructed to work "quietly on their own" and there was little autonomy since the teacher usually provided directions as to how an answer was to be reached or how an activity was to be carried out. The parameters were externally set either by the curriculum or by the teacher.

Nov.6, Wednesday (S1a)

T2 (proceeds to define the assignment): It's to be a diary of

Anthony Henday. . . . Children piece together who Anthony Henday was . . .
T2 (directs them how to start off): Title, date, "Dear diary", time of entry . . .
T2: Enter your daily activites . . .(begins and example) " I arose at 5 a.m., and prepared to break camp . . .
They are to cover 5 days . . .
B5: Can they make a map at the end? (not noticed)
T2 explains what he wants . . .
B7: Why can't we use different dates?
T2: Because we need a starting point .

:

B6: Can we write a story. (he and T2 negogiate here.) . . . Can we have a different title?
T2: No!

:

There were occasions, however, when individualism had a greater influence.

Nov. 12, Tuesday

:

They are to read their diaries. . . .T2 plans to go down the rows and they are to come to the front to read.
B6 tells me he's still working on Day 1 'cause he has details. He shows me two pages. When G6 is asked to read, she refuses . . . T2 agrees to read it for her . . .

:

G3 reads hers, she's written in the third person. T2 compliments her.
B6: Has it got to be 5 days?
T2: Write shorter entries.
B6: No, I'll stay up all night.

:

G1: Is it OK if I read about the day before I start out. (i.e. the night before "Henday" goes to explore). T2 compliments her.

:

S2 - Near Equilibrium

In the regular small group context, children again had minor input into the setup although they had more choice than in the regular classroom context.

Oct. 17, Thursday
. . . (introducing a trading game, using Dienes blocks) . . .
TR: I want you to play with it. You can choose addition or subtraction
B1: What about times?
TR: No!
I explain the addition version (They are to each roll a die to

determine the number of units they may take. They add the new amount to the previous ones and may trade for tens, or hundreds when appropriate number of units are available.); B1 catches on . . . he's able to echo how a subtraction version would go.

:

G3: How am I suppose to do this?
I'm showing B2 . . . G1 explains it to G3 . . . I explain further
G3: Can I put in (a)10, take out 5 (units).(She rolled a 5)
TR: Yes! (this was what I had suggested)

:

Oct. 29, Tuesday

G1 notices we didn't do "Tune-Up". B1 asks if we're going to do it. I confess that the game they played last day contained these "sums".
G2: Yeah, I liked the game.
B3: Can we play it again?
TR: We can as soon as B2 gets here and we get started. . . . (get involved in intended session involving problem posing and the game is not played.)

:

Much of the activity was oral and children's ideas were expressed in this capacity.

Nov. 21, Thursday

:

TR: If you would look in your own books
B3: I know this, I know this.
TR: Good. Just find page 72. Ok, who can tell me what an even number is?
(B1 and G3 provide numerical examples) . . .
B3: It's a number you can split.
TR: What do you mean by split?
B1: Split evenly
B3: Like six, 3 and 3.
B1: You can divide it in half.

:

TR: OK, now then, B3 is going to give us what? an odd number?
B3: Fifty-five thousand and six hundred
TR: 55,600 (I'm repeating after him)
B1: I can give a large number.
B3: So can I.
TR: We're still waiting for this one.
B3: and fifteen.
TR: 55 615 , is that odd? 55 615?
B1: Yeah, yeah .

:

TR: (they had been giving examples of an even number times and even number) . . . Great, looks like an even times and even . . . (I acknowledge B1's hand.)

B1: 10 x 5
TR: 10 x 5 is what? is that an even times an . . .
B1: 10 x 5 would be one. (he's annoyed)
TR: OK, is 10 even?
B1: Yeah.
TR: Is 5 even?
B1: No.
TR: So you're talking even times odd now.
B1: Yeah but it ends in zero.
TR: Yeah, so it ends up being an even.

The pre-determined curriculum still had a tremendous influence on the concepts covered by the researcher and although there were fewer exercises to complete, the text was still used for this purpose. The proximity of the children encouraged more "talk" and "interaction" than that observed in the regular classroom. There were also occasions in this setting where individualism had greater influence on the "agenda".

Oct. 22, Tuesday

(I plan to have them use the abacus to do exercises with larger numbers today.)
TR: Can you represent the number in exercise 1(a) on the abacus?
B2 does it first, but in the thousands, hundreds and tens columns.
B1 tells him it's wrong.
B3 redoes it.
TR: Then add 388.
Girls do it cooperatively.

I ask them to do c, e, h. Boys share each exercise. B1 begins.
TR: Do it on the abacus, then write it in your book. . . . B2 makes suggestions to B1; G1 does the first one for the girls.

B2 does e. . . B1 works out h without the abacus . ... B3 has e figured out before B2 finishes. . . .
B2: You're not suppose to go ahead. Do h , B3!
TR: (to B2) They've decided not to use the abacus. . . . (he wants to.)
Girls work away with abacus. . . . girls are ready to do number 3. They ask if they do it on the abacus.
TR: Up to you!

Nov. 19, Tuesday

TR: (I explain what I'd like them to do on p. 63) Find one (exercise), then I'll ask each to ask someone one of them.

B3: Write it down?
TR: I'll start. G3, . . . number 24?
B1 knows, B3's hand is up . . . G1 shouts 30.
TR: That doesn't help.
B1: OK, I'll do the next .
TR: Do you know how you got 30?
B3: Just add 5 onto that (points at the exercise on the board)
B3 begins to quiz B1 : Number 16?
I try to delay them. B1 gives the answer; B3 asks B1 for one. B1 assigns number 14. I see what they're doing and I say that's not what I meant; is it what they want to do?
B1 and B3: Yes!
Then I ask the girls if they want to do it between them, rather than asking the boys? They agree. . . . Boys are well on their way. I get the girls started . . . I tell G2 to begin.

S3 - Far From Equilibrium

In the enrichment group setting, initially, the researcher simply provided directions but in certain later sessions she too was a learner and interacted more in this capacity.

Oct. 17, Thursday

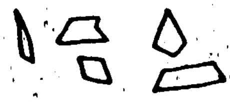
TR: (to G3) . . . Let's remember we started with a square. Why don't you think about doing a journey today? (I go to explain journey B1's way . . .) Trace the second shape, cut it, and so on.
G1: Then you have to glue that together.
TR: Let me show you a journey I made . . .

I come over to trace G3's . . .

G1 has traced the outline of her shape; she doesn't know how to cut it.
G1: Do I have to get it back to this (holds her second shape)

TR: You need to return to a square.

I go to have a look at B1's and help move some pieces around .



Nov. 19, Tuesday

G3: Can you help me hold these?
TR: Yes, while you're trying to trace it.
G2: I can't make it!
TR: Yes you can; I've seen you make loads of good ones.

G2 asks me to help her trace it. . . . She waits for me to finish with G3.

B1: TR will you help me trace this?
I accept . . .

Oct. 29, Tuesday

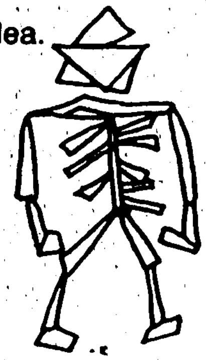
I begin to make my skeleton. . . . Everyone's working at something.

I'm reminding B2 to use all his square . . . I go back to my skeleton.
B2: That's a skeleton?
TR: I'm trying.
B2: Oh!
B3: Skeleton's are hard.

B2: That's a skeleton? Look, B3!
B3: A funny skeleton. (They laugh)
B1: What's that?
TR: His shoulders.
B2: Don't you know what skeletons look like, it has shoulder blades, doesn't it?
B1: Not that long.
B3: You didn't use all of it.
TR: I'm not finished . . .

B1 says he can't do anything with these triangles. . . . I go to have a look and suggest he spread them out.
G1 mentions my skeleton to G2. G2 says it's nice and tells G1 to make one too.
G1: Use the large triangle for his head and use the others somewhere else.

TR: That's a good idea.



Nov. 5, Tuesday

TR: I can't seem to get this one done.

B3: I did that one, it's easy.
TR: With one bag? Ok, I got to try and figure it out then.
B2: Here, I'll show you.

TR: OK, give me a minute, then if I don't get it, you . . .

TR: Do you know how to do it, B2, to show me?
B2: I never did it but I could probably make it anyway.
TR: You sure you did it with just one bag, B3?
B3: Yeah, I have to find it and show you I did it.

TR: Oh, I got it! Alright, I got it with one bag.

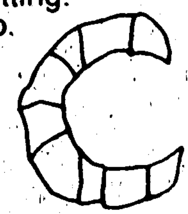
B3: Look at how easy this one is.
TR: It's a square! Well how many ways could you do it? That's the easiest way.
B3: I don't want to try other ways.

I'm struggling with mine. B3 and B2 say it's easy. I complain 'cause that's what they always say.
B2: Here, let me show you!
TR: OK, show me.

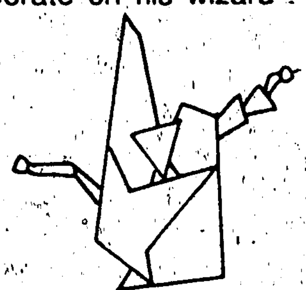
Children were encouraged to work together if they chose to do so, and, as was described earlier, their input often directly or indirectly influenced the evolution of the group's activities. The researcher did attempt to set parameters at various times but usually these parameters were not constant nor necessarily consistent; nor was the authority strong, since children often ignored the request and followed their own desires.

Oct. 28, Monday

G1 is making a moon. She says she'll cut out the moon, then cut it in pieces.
TR: Today when you make something, try to remember to make it out of pieces, rather than just cutting.
G1: Draw moon then just cut it all up.



B3 wants to elaborate on his wizard . . . put a hand zapping the cat.

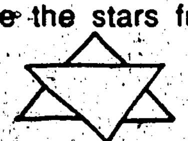


. . . I mention G3 is going to make us some stars; G2 volunteers too.

TR: You're not going to draw a star?
G2: Should I erase the pencil lines after?
G1: I drew my moon.
TR: Ohhh.
B2 shows me his figure . . .

(I don't finish my comment to the girls).

G2 tells G3 to make the stars from two triangles, overlapping.



G3 makes a star from 4 triangles.

G3: Is that a star?
TR: You know what, it looks like a flower. We could put it on the grave.

Oct. 29, Tuesday

:

G3: Can we make another one?
TR: Well not, quite as big. . . . the cats, pumpkin, witch were made by folding and cutting . . . the work I've been doing with you is we start with a rectangle or square
B3: That's what I did.
TR: and we used all of it . . . use to fold it to cut.
G1: That's how we did the cat.
TR: But, G1 admitted she drew her moon and then cut it.

:

TR: What I thought, I'd like to do at least one Hallowe'en thing from each of you - like that.
B1: Own little mural.
TR: Sort of.

:

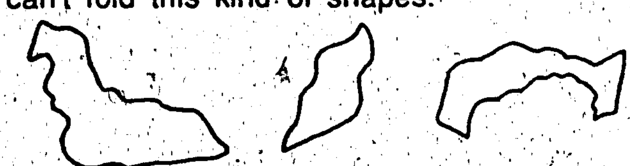
TR: No just cutting or squiggly cuts.
B3: Can we mix up colors?
TR: No, you have to start from one shape and use all of it. (This disappoints B3)
B1: Can we cut out what we need?
TR: No, I want you to use shape, do something like I did with the witch. I know it's different but I know you can do it.

:

B1 is cutting squiggly - dragon's head.

:

TR: Start with some shape, use the whole shape. You're going to fold to cut.
B3: No we don't have to fold do we?
B2: Yes.
B1: Do we have to fold?
TR: OK, you can do that . . . at least do one thing on your picture by folding before you cut.
B1: I can't fold this kind of shapes.



TR: I know, that's one restriction. . . . but make at least one thing - even a simple little thing.

:

B3 shows me what he began with and folded it.
I stop at B2's seat; he seems to be just cutting. I suggest we look for the square he started with, so he can use it all.

:

B1: I'm going to make an airplane and cut it.

:

<u>Summary</u>

Thus if we signify the regular classroom (S1a and S1b) as the equilibrium state of the research study, the small group instruction setting (S2) would be viewed as near equilibrium mainly because of the similarities in the curriculum utilized and the structure. The enrichment group (S3) then would be far from equilibrium both in terms of the curriculum and the structure.

Fluctuations and Distance from Equilibrium

Since Prigogine and Stengers (1984) stipulate that a major determining factor of the distance a system is from equilibrium lies in how fluctuations are either dampened or amplified, it is essential to explore the presence or absence of fluctuations within the three settings in order to further explicate the settings' "thermodynamic" status. Moreover, it is pertinent to discuss the effect these fluctuations had on each "system" as a whole.

An overview of the data revealed numerous ways to view fluctuations in these settings. There were distinct fluctuations in the curriculum at particular intervals over the three month period. There were fluctuations in the physical arrangements preferred by the child at specific times. There were daily fluctuations in both the children's behavior as well as the children's ideas.

Fluctuations in Curriculum

Over the research period, in S1, three chapters were covered in mathematics and in social studies. In both subject areas, when a chapter was completed, a test was given, and then the next chapter was begun. These distinct divisions were not visible in the Music and French classes which were observed and in Science there was only one chapter, a test, and a second chapter begun while the research was carried out. In S2, the trend was similar to the regular mathematics classes in that although the methods used to teach the chapters were different, one chapter followed the other in sequence. As suggested by Prigogine and Stengers (1984) then the path following a bifurcation point at equilibrium or near equilibrium depends largely on control parameters. If we view a chapter's end as a possible bifurcation point, we see that what happens next is controlled by what follows in the text or at least the teacher's guide. The children had little influence as to what came next in these settings.

In S3, there were no chapter demarcations as such. As indicated in the earlier discussion of the curriculum, specific "switches" were made over the duration of the research. What began as "do anything" was restricted to "flat figures" from paper folding; the "journey" theme was followed by the creation of a "Hallowe'en mural"; the "tangram" episode was the next alternative followed by the "making of tangrams". In this setting, then, the path chosen following possible bifurcation points depended more on "chance and necessity" as Prigogine and Stengers(1984) suggest occurs far from equilibrium. That is, there were several possibilities the children and researcher could have pursued but at a bifuraction point one path was actualized sometimes by all of the group simultaneously and sometimes by different individuals over a course of a few days. External control parameters minimally determined the next move. As the study progressed such parameters became even less determining.

<u>Fluctuations in Physical Arrangements</u>

The fluctuations in the desired physical arrangements were experienced in all three settings, but the system's dealings with them differed. During regular classes (S1a and S1b), for instance, there were occasions when children desired to work on the floor, or at the back of the class or to one side. However, usually, these children were asked to return to their seats like everyone else; although on certain occasions certain children, B3 and B1 in particular, were permitted these digressions.

Sept. 25, Wednesday

B3 leaves seat to work at back . . . B6 comes back as does B7.
T1 (speaks to B6): You can see it from your seat.
B3 is spoken to but he defends himself and stays.
B2 at back with B3 . . .
B2: If this is a farmer, who's that? (referring to two pictures on the French bulletin board which look similar).
When T1 calls B2's name, he immediately provides a reason for being at the back, even though it is not requested.
T1: Is there a question?
B2: No. (Later) *If that's the farmer, what's that?* (points to le jardiner)
T1: I did not give it as it is on the bulletin board. You should have paid attention.

Nov, 13, Wednesday (S1b)

writing essay on Fort Edmonton . . . B1 worked on the floor for the whole period. . . . T2 permitted him without comment.

There were other occasions, during classes such as science, that children ignored the teacher's instructions with respect to staying in the classroom area yet they were not pulled back immediately. This always occurred during the last period of the afternoon.

Oct. 30, Wednesday (S1a)

Last period . . . (shared reading with grade 2) . . . T1 passes back the grade 4 stories to them. Now they are to find a corner to read with each other. Some ask if they can go over to the "open area" (outside regular classroom boundaries) . . . they are told to keep in the classroom area. I notice later that several boys groups did go to the "open area" . . . Towards the end T1 calls them back to their seats . . .

In S2, however, minor fluctuations in seating were permitted. Indeed, children usually chose the desired arrangement and it was accomodated.

Oct. 8, Tuesday

. . . They use pillows, sit in a circle on the floor. B3 sat at the table at first. . . . They work on the worksheets . . .

In S3, fluctuations of this type were permitted openly for the most part also.

Nov. 13, Wednesday

B1 goes off to the back , away from the table.
TR (mumbles): I'm going to make a different tangram.
B2 goes over to where B1 is . . . later returns to table.

G2 moves to the floor, finds it too difficult (to work there). . . B2 asks B1 to try his "tangram puzzle" and goes to the back where B1 is. . . they swap puzzles and work on them .

Nov.20, Wednesday

B3 is seated over by B1 . . . B1 comes to get me to make B3 move. I speak to them about space . . . B3 positions himself away from B1 at the other end of the desk

Fluctuations in Behavior

In all three settings, there were fluctuations of behavior exhibited by the children. That is, some children did not conform to the expected behavior associated with an assigned task. Such non-conformity was at times disruptive to the assigned task, while at other times it was conducive to the activity. There were also examples of alternate behavior which was not noticed by the teachers involved. Although, the toleration of fluctuations in children's behavior varied in the three settings, it was apparent that fluctuations in behavior that were perceived as disruptive were dampened in all three contexts.

Oct. 2, Wednesday

. . . French class began well, but got hectic when B4 kept the cheque T1 was using for the demonstration. Several children jumped out of their seats, tried to get it from him. There was shouting and holding. T1 waited it out and then took it from B5 who was the one to end up with it. The routine was restored again but while they were repeating the vocabulary, the cheque fell from T1's pocket and B4 ran up to snatch it, T1 grabbed it first - laughing ensued with T1 included. The class was quiet as T1 assigned workbook exercises; B4 and *B3* were sent out of the room - to the library to insure that the class returned to the routine. T1 detained them (the class) until work was finished.

Oct. 16, Wednesday (S1)

Science . . . T1 tries to begin experiment. . . . First attempt to get started ends in running and grabbing materials. She sits them down, changes the rules and assigns a comb to each row. They must work in the assigned groups now. . . .

Oct. 17, Thursday (S1)
(At the beginning of social studies period, some homework has been returned and T2 is reviewing what corrections should be done)
. . . T2 repeats for *B3* how extra effort is needed to do well for him. T2 had already told the class (while B3 was away.)
B3 and B5 are sitting at opposite sides of a U formation, yet they entertain each other by pretending to eat their pencils. *Even though B3 seems inattentive he answers most of the questions asked, usually well.*

Oct. 23, Monday (S1b)

Music . . . T3 tells B2 to raise his hand to talk. After a couple more times, she isolates him again by having him sit on the front step by himself. . .

Nov. 12, Tuesday (S2)

B2 and B3 are not paying attention (B3 plays with a container of powder). I take the powder, but they still attend to it. I threaten them with either they give me their attention or they return to the classroom. . . .
B3 takes the powder and dumps it. Again a distraction. B2 gets up to look and talks to B3 about it.

Nov. 26, Tuesday (S2)

(When he finishes the sheets, B1 sits on the floor and proceeds to rearrange the sheets in his binder)

Girls are done! . . . I ask if they'd like to play the game.
G1 and G2 : Yeah, yeah!
TR: We'll need space.

(B2 and B3 join us,too, to play the game.)

Nov. 21, Thursday (S3)

B2 and B3 fly planes. . . . B1 starts to write on the chalkboard.

As I carry B3's set to a "safe place" . . . B3 flies his plane again. B2 has returned to his cutting . . .
TR: B3, I'm not going to ask you again. Please!
B3: Yeah, I'm going to start .

B2 has made another airplane; he rises, goes to B3 and then flies it toward "social studies" class. . . B1 asks where it landed.
B2: In the garbage.
B1: That's where it belongs.

B2 . . . talks to B3 and then flies the plane over the divider. B1 stands on a chair and flies his small plane. . . . (I'm helping girls with the task.) . . . B2's plane hits the table where we're working . . . I go to speak to the boys.
TR: Enough! (to B2) Are you with our group or not? . . . I stand . . . and quiet them.

Fluctuations in Ideas

The fluctuations in ideas which the children exhibited were also varied; some were extensions to the task while others were unrelated. Such fluctuations were dealt with differently in each setting. In the regular class when discussions expanded beyond the question asked or children detoured from the topic, they were usually brought back to the topic by the teacher. In certain cases, the digression was addressed and dismissed as invalid; in others it was ignored and the proposed activity was followed irrespective of the fluctuation so that the child or children gave up. There was little evidence of the teacher using the digression to guide the event from that point on.

Oct. 4, Friday

Some children read their legends . . . G5's story of how buffaloes got their horns stimulates discussion; *B2* and B6 extend the story. . . . *B1 mentions porcupines shoot quills* and this leads to arguments and *B3's explanation* . . .
T1 permits the extra discussion (in between story readings).

Oct. 16, Wednesday

B8 brought bullets . . . they talk about it . . . children get excited and share stories. T2 doesn't let them digress too much. *B2 brings up Bugs Bunny incident where placing a finger in the barrel of a gun causes it to backfire*. . . T2 immediately points out that Bugs Bunny was taken off the air because of violence and because it showed things that weren't true.

Nov. 7, Thursday

writing diaries . . . *B2 draws a map* , B6 watches and asks questions. . .
T2 tells *B2* to put it (the map) away.
B2 protests . . . T1 encourages B6 to work on his own. . . B6 shares his ideas with *B2 who provides feedback*. . .
T2 tries to get *B2* back to work . . .

In the regular small group, children's fluctuations of ideas were at times manifested by their choice to either use or not use the suggested aids, i e. doing the exercises their way. Towards the end of the study, the fluctuations were also manifested in their personal interpretions of the assigned task, i.e. carrying out an assigned activity their way. These digressions were accepted and at times encouraged, although often prefaced by "that's not what I intended".

Oct. 17, Thursday

TR: I want you to play with it. (meaning a trading game using Dienes blocks) You can choose addition or subtraction.
B1: What about times?
TR: No!

Oct. 22, Tuesday

. . . B1 works (h) out without an abacus. . . TR starts B1 on number 3, with instructions he can use the abacus or not.
B2 wants to use the abacus; girls work with the abacus. . . .
Girls choose not to use the abacus for number three.
B2 still using the abacus . . . TR: Don't take too long. Can you do them without the abacus? . . . B2 shrugs. . . TR: It doesn't matter, I just thought it was slowing you down.

Oct. 29, Tuesday

G2 liked the game we played last day . . . B3 asks if they can play it again. TR: Yes as soon as B2 gets here and we get started. (But, the game is not played)

Nov. 19, Tuesday

TR explains the concepts on p. 63 and instructs: Choose one of the exercises and then I'll ask each of you to ask someone else one of them . . .
B3 begins to quiz B1 and B1 in turn quizzes B3. TR tries to delay them.
TR: That's not what I meant; is it what you want to do? (permission is granted for them to continue their way.)
Girls are encouraged to do the same.

Nov. 26, Tuesday
B2 circles any groups of five.
TR: You're suppose to keep the rows.
B2 laughs and ignores the task. TR threatens him with the principal.
B3 works out the fact 5x8 although not required on the worksheet. He is allowed to do so, but not much encouragement from TR.

In the enrichment small group, individual fluctuations were, for the most part, accepted. There were occasions when the researcher attempted to negotiate the child into doing it "her" way but when the fluctuation was strong enough, for instance, the boys' method of cut and paste without folding, it continued to exist and was not pulled back to equilibrium. The "count sides" episode reported below is an example where children's ideas mushroomed when they digressed from the assigned task.

Oct. 3, Thursday
. . . B1:(sizes up his shape) A pyramid on its side.
TR: It's an irregular shape.
B1 starts counting the sides.

B1: There.
TR: How many sides?(I count; I get 10.)
B1: You counted that one. . . . (he wanted eight!)

B1: I've made an irregular shape.
B1 is counting his sides.

B1; Eleven sided, what do you call it?

[NB. This pursuit continues over several sessions and B1's interest in "naming" figures grows. B3 also becomes interested.]

Oct. 10, Thursday

B1: OK, let's see how many sides this has. I'm going to count all the little uneven sides and everything. . . .

B3 shouts: B1's got 31 sides so far! (B1 counts louder 32, 33, . . . 45).

B1: I'm going to make one with more than 45. (B3 and B1 discuss it).

B3 claims he can make one with more sides than B1's. . . .
B1: Can we make a figure with the most sides in the world?

Nov. 15, Friday

TR: Do you think you'll be able to do one by folding?
B1:Probably,I don't know .
TR: Maybe one of these days you could try; just means folding where you would "draw".
B1: The one I'm doing has extra pieces.

B1 finishes that one.
TR: Now are you going to do it a different way again?
B1: Yeah! . . . I'm going to cut out some pieces, you know like, let's see, there was 2 big triangles in the pack, 2 little ones. I'm going to cut up . . . then just move 'em all around and make some shapes:
TR: . . . That sounds clever! . . .

B3 chooses an orange square.
TR: Fold it.
B3: I hate folding; I don't like paper-folding.
TR: How do you know?
B3; I did it before (referring to earlier sessions.)

B3 has his shape drawn and wants to trace it.

Nov. 21, Thursday

G2 asks G1 if she traced tangrams from the set; G1 admits that's what she did. . . .
G1: G2, would you help me make a shape? I'm no good at it. I got an idea, I'll use one from the box. (She heads over to the corner to get a box of tangram cards).

G1 offers a card to G2 to try. . . . (G1 is filling in a card with

her pieces which when completed she then redoes on her own paper and traces as a card for her set).

G1: TR, could you help me make this thing and then I'll do it. (She refers to card from the tangram sets).

I go to help. . . As G1 and I try to figure it out, G3 gets involved too.

<u>Summary</u>

Data have been presented to establish that the three contexts which emerged in this study possessed characteristics Prigogine and Stengers (1984) would attribute to systems at, near, and far from equilibrium. The third setting (S3) was seen as far from the equilibrium of the regular classroom both in content and structure. At no time was there an attempt to draw the enrichment small group back to a status comparable with the regular classroom. Rather special effort was made to maintain a flexible and open system which, in the course of activity, could deviate even further from the equilibrium of the regular class. This difference was also noticed by the children involved who indicated in an interview afterwards that a key ingredient in the enrichment small group was the interaction between them which drove the system. Table 1 provides a synopsis of the three settings.

TABLE 1 : A Synopsis of Settings as "Thermodynamic" States

	Regular classroom (S1a and S1b)	Regular small group (S2)	Enrichment small group (S3)
Individual influence	Minimal	Minimal	Maximal
Independent entiities	For the most part	Pair work encouraged	Coherence
Control parameters	External; closely adhered to	External; some flexibility	System members set parameters
Behavior of system	Routine; predictable	Fairly predictable	Unpredictable

As Prigogine and Stengers (1984) suggest, in far from equilibrium systems, individual behavior can be decisive and was in S3. Whereas in S1a, S1b and S2 individual actions were usually dampened by an authority, the individuals in S3 largely influenced both its direction and its development. Children did work as independent entities in all three contexts, however, the children in S3 exhibited a higher awareness of and concern for what the others were doing. In S1a, S1b and S2, children set about to complete the assigned tasks on their own, and often when they did interact, it entailed checking what the other had done; on the other hand, in S3, children showed keen interest in one another's ideas, made suggestions to one another and even at times attempted to keep the group as a whole together. The girls in particular, in this setting, developed a close network of support. The parameters in S3 evolved from discussion with and suggestions made by members of the group or system. In S1 and S2, one major parameter was the predetermined curriculum and the textbook itself; both of which were largely imposed on members of the system. The activity of the enrichment small group was highly speculative, and what would happen next was seldom predictable. Where a comment or idea might lead was largely dependent on the "moment". In the regular classroom, and even in the regular small group the flow of events was much more predictable and routine. In the regular classroom children would do for the most part as they were told. In the regular small group, there was some chance involved but for the most part children complied with authority and the program went fairly much as planned.

Based on the treatment of fluctuations within each setting, the regular classroom (S1a and S1b) exhibited the characteristics of a system at equilibrium; the regular small group (S2) exhibited the characteristics of a system near equilibrium; and the enrichment small group (S3) exhibited the characteristics of a system far from equilibrium.

CHAPTER V

DATA ANALYSIS

The focus of the data analysis was a search for the presence or absence of autopoiesis in the three settings of the research design. Both individual autopoiesis and social autopoiesis were relevant and even though examples of these were presented separately, individual autopoietic systems were not distinct from social autopoietic systems but rather coexisted synchronously. Thus, evidence of individual autopoiesis was necessarily embedded in ongoing social contexts. In describing this phenomenon, orienting remarks [enclosed in brackets] are made as asides throughout the transcripts to provide a possible focus for their interpretation.

Individual Autopoietic Systems

The individual autopoietic systems examined were those involving child/material systems. That is, individual children interacting with the materials were seen as a system which possessed autopoietic potential.

S1a and S1b - Individual Autopoiesis

In this context, materials were generally very structured, i.e. in the form of worksheets or text exercises, and the directions for working with the materials were given by the teacher or the text. Thus, children's interactions with the materials were determined largely by outside forces. The child/material system was not permitted to be self-generative. Individual children did as they were told and the processes of production within the child/material system were dictated by external agents rather than generated by the components themselves.

Sept. 26; Thursday (S1a and S1b)

> . . . Mathematics . . . T1 corrects the "Tune-Up" exercises on p.20 by asking each child to give a solution. . . . T1 talks of

different forms of subtraction, namely 67 / -24   67-24

t	o
6	7
-2	4

T1: Which do you prefer?
Most choose the first; few like the latter. Some said they could use them all or the first two. T1 assigns 12 exercises, (and directs them to) use the chart form. . .
(No child is noted using an alternative form or technique.)

[At a surface level, the external agent (teacher) seems to permit a small degree of autopoiesis (i.e. preference); yet, this is eradicated by her insistence on one format only. Child/material system therefore controlled by external parameters of both teacher and algorithm.]

Oct. 28, Monday (S1a)

. . . T1 is doing symmetrical shapes . . . Bat, Owl, and Witch.
T1: Have you heard the word symmetry?
Many say yes.
T1 (shows the shadow of 1/2 of a figure): What would happen if this overlaps?
The children recognize it as a bat. T1 gives them the paper; they're excited.
T1 (then instructs them): Take the paper and fold it in half. Put him (the bat) at the top so we can use the paper again. Copy the shape from the board.
. . . T1 traces the outline of her bat on the overhead; the children are to copy her movements. T1 calls out each step . . . head,ear, . . .

[External agent (teacher) controls production processes; child/material system develops in a determistic fashion.]

I notice T1 shows half of a "witch" . . . some say it looks like a tree.
T1: You have to put eyes and add feet.

T1's class is noisy, most are cutting their shapes. Now, T1 traces the original on the paper for the children to cut. T1 comments about getting good and then coloring. . . (T1 implies) today being practice . . .

(All children seem to follow directions closely since there are no deviations in the shape of the "products".)

[Products are "technically" good but are "outside" the child/material system similar to an allopoietic "machine" which produces "bolts".]

Oct. 10, Thursday

Social Studies . . . T1 reviews a worksheet they did last day

> and plans to do a follow-up. T1 uses a map to point out areas where Indians were . . . Individual children read parts of passage (the handout). . . T1 asks (oral) questions about the paragraph . . .
>
> [Child/material system has limited control over generation of ideas, although constrained by text and teacher expectations]
>
> Children are then assigned questions on the worksheet similar to those asked and answered orally. . . .
> T1 (hands out next page) : Work quietly on your own. (T1 also tells them what colors to use to color maps.) . . .

Likewise, in S1, the criteria for the child/material system were also externally set and children attempted to meet an outsider's expectations, i.e. that of the teachers, rather than judging their experiences on the basis of internal coherence.

> Nov. 13, Wednesday (S1b)
>
> . . . Today, T2 wants them to write a one page essay on the most exciting part of their trip to Fort Edmonton.
> B2: What if nothing was exciting?
> T2: Just write about the trip.
> B3(excited): I want to write about the trading post.
> B2: Why a whole page?
> T2: Because I figure that's how much you can write in one period and I intend to collect it.
> T2 tells them how to begin; children ask if they have to. . . .
> T2 writes the beginning sentence on the board . . . "The most exciting" . . .
> B1: I used fascinating?
> T2: That's OK if it's spelled right. I expect no talking, simply a flurry of pen on paper.
>
> (Children question T2 with respect to details like names of places, i.e. chief factor's house, . . .)
>
> [Child's autonomy surfaces briefly in questions of external criteria; however, allopoiesis dominates as children do as they are told.]
>
> Nov. 20, Wednesday (S1)
>
> T2 plans to return their essays on Fort Edmonton;T2 has "red-inked" them and he wants them to write a good copy today.
>
> B1: Can we start right now?

They are told they have 15 minutes to write the good copy. Then they'll read them to the class . . .

Very quiet now, everyone working on their own essays. . . .

(At the end of class T2 collects both copies in order to check to see they made the reccommended corrections . . .)

[External criteria is the driving force behind task and the internal criteria of child/material system was not considered.]

As the excerpts illustrate, even when the potential for creativity and spontaneity was present (Oct. 28, Nov. 13), the authority, i.e. the teacher, played a major role in determining and judging the interactions between the child and the material. Hence, the child/material systems exhibited allopoiesis.

However, despite the restrictions, there were some episodes, in social studies in particular, where some child/material systems exhibited autopoiesis. In the Nov. 13 episode for instance, children did write their own reports and, thus individuality to a certain extent was exerted on paper, in that, they generated their own stories. A similar writing assignment which evolved over several days proved to be an exemplary case where the experience permitted autopoiesis for at least some of the children. One child/material system, namely B6/diary in S1a, was indeed autopoietic irrespective of the constraints. As can be seen from the observations, in this instance, a child interacting with the "task" was the overriding factor which drove the system; the child's desires and ideas led to the generation of the event.

Nov. 6, Wednesday

. . . T2: The next topic is another writing assignment. How does that sound?

T2 proceeds to define the assignment; it's to be a diary of Anthony Henday. . . . T2 directs them how to start off, i.e. title, date, "dear diary", time of entry, . . .

T2: (begins an example) I arose at 5 a.m. and prepared to break camp . . .

They are to cover 5 days . . . T2 will give them one other class to finish . . .
B6: Can we write a story? (He and T2 negogiate . . .)

[Initial conditions, even though somewhat deterministic, hold potential for mutual causation, i.e, negogiation.]

Nov.7, Thursday

. . . T2 reminds them they have this period to work on their diaries . . .

B6 shares his ideas with B2. B2 provides feedback like an explorer wouldn't hunt. . . . B6 starts a story . . . .

[Child views initial conditions as perturbations and sets in motion compensatory actions, i.e. writes story without teacher's permission.]

T2 reminds them he expects them to read their diaries on Monday . . .

Nov. 12, Tuesday

. . . they will read their diaries.
T2: Everybody will read. . . .
B6 (to me): I'm still working on day one 'cause I have details: (he shows me two pages) . . .

B6 : Does it have to be five days?
T2: Use shorter entries.
B6: No, I'll stay up all night.

B6 asks to read when he's finished that day. When T2 calls on him, B6 says he has 5 words to go.

[Child/material system takes on autopoietic behaviour; it is a self-generating system wherein organization, i.e. identity, is maintained. External criteria viewed as perturbations, not input.]

Nov. 13, Wednesday
. . . B6 (mentions to TR) the possibility of rewriting the diary, indicating he hopes to get a computer for Christmas and he'd like to redo it then. . . . T2 sets the deadline of tomorrow for the diary to be handed in. . . .

[Child/material system continues to generate ideas.]

Nov. 18, Monday

. . .As B6 joins others, he says he's still working on his diary - two days left to go.
B1: You'll get zip! It doesn't matter how long it is.

[Internal criteria of the autopoietic child/material system, i.e self-satisfaction, supercedes the external criteria of grades or teacher approval.]

Likewise, this same episode of diary writing permitted others, including children from the subgroup, to exert some autopoietic tendencies with respect to the "product". G2, for instance, wrote a very long diary, about 13 pages, but she was concerned that it was too long. Other personal preferences were incorporated by other individuals, too, as was evident during the oral readings.

Nov. 12, Tuesday

T2: I'm going to have one hour of Social and we're going to read the diaries. . . . Everybody will read . . . (T2 wants them to come to the front and read)
B6 (to me): I'm still working on day one 'cause I have details. (he shows me two pages) . ... (The reading has begun)

When B3's turn comes he doesn't know which (day) to read. . . He shows class a small map he drew in context. Others say they drew maps . . . G3 reads hers; she's written in third person . . .

. . . B1 reads . . . shows map. . . . G1 . . . has a unique start, she writes about the night before Henday sets out to explore . . .

G8's entry is different . . . stayed home, slept and dreamed . . .

[Within the "surface" constraints of the activity, i.e. time, and format, child/material systems are able to generate their own ideas. The products, i.e. the diaries, for the most part are generated from within the system.]

Thus within this social studies project, self-generation on the part of the students was evident. The child interacting with ideas produced more ideas which evolved into a "diary"; some technique was employed but creativity was also possible. Within such a context, autopoiesis was released rather than inhibited. However, in the regular classroom setting (S1), the child/material systems were for the most part allopoietic.

S2 - Individual Autopoiesis

Even though there was less show and tell by the teacher (TR), children still relied on their earlier experiences to determine their child/material interactions. That is, children were heavily influenced by the textbook structure, thereby employing known techniques to complete the assigned exercises. When the text was not used, children still requested outside direction and their questions indicated that they did not see themselves as "in control". For the most part, the child/material systems here too are non-generative, non-spontaneous and external criteria still exerted a large influence. Even in later episodes when the potential for creative activity was greater, little of the children's organization was present.

Oct. 29, Tuesday

TR: . . . open your math book to page 45.

TR: I'm going to give each of you a card and you have to make up your own problem.
B1: Do we have to write or do we, 51 (moves hand in the air as if writing a "sum")
TR: Not a sum, that's too straightforward; a problem like on page 45.
G1: Do you have to write equals?
TR: No.
B3: A number divided by a number plus a numb[illegible]es a number.
. . . I read one of the problems (in the text) . . .
B1: Do we write a word problem?
TR: Right!

TR: Then we'll swap problems.
G1: One teacher, two students, how many?
TR: That's the restriction, it has to be in the thousands.

B3: Can it be a million?
B1: Billions?
TR: As large as one hundred thousand.
B2: What do you mean? We're suppose to write like, in July they shipped?
G3: On any subject?

TR: Yes, anything.

B1: Can it be 100 000's each day?
TR: What do you mean each day?
B1: Monday to Friday.
TR: OK, but that means a lot of numbers.

B3: Can you tell them to add, then divide, then multiply?
TR: No, you're to ask a question?

(Problems which the children write are very similar to those in the text.)

[Minimal autopoiesis exerted; children seek external criteria and parameters in an allopoietic tradition of being determined by outside "agents", i.e. teacher and text.]

Nov. 5, Tuesday

TR: Today we're going to work with measurement. B3 just mentioned centimetres.
(We discuss different metric units)

TR: Stay in the area; the instructions are on the board. Write an estimate down. (They are to measure objects with their rulers, using different units.)

G1: For number 2, can it be your whole body?
TR: Yes.

TR: Can you follow the instructions? Ok, you have this period to do as much as you can . . .

Others are looking around for objects (to measure). B1 wants to measure the floor; he starts to measure a box. . . . (B2 and B3 measure each other's height) . . .

G2 tells me her guess and measure . . .

I bring to B2's attention that when measuring parts of the body I requested they use decimetres; he was using centimetres. We talk about how to change it . . .

B3 asks about number three; he doesn't quite follow the instruction. . . .

G2 asks for a suggestion of what to measure.
TR: . . . foot. . .

[Initial conditions rather deterministic since choice is limited; child/material systems mainly do as they were told. Some individual autonomy present.]

It is evident that in the S2 setting, child/material systems were again largely controlled by outside expectations, if not of the immediate teacher then of the curriculum in general both past and present. When assigned exercises, for instance, although no overt comments were made by TR as to which technique to use, children employed learned algorithms. For the most part, self-generative activity was limited. As illustrated, in the "problem posing" episode, each child composed only one problem as was initially requested, and little of the child's personality was evident in the product. Likewise, although children chose what to measure, their techniques were traditional and came from earlier experience with rulers. Thus, in the "regular small group" (S2), autopoiesis of child/material systems was often overshadowed by allopoiesis and consequently individual autopoiesis was inhibited.

S3 - Individual Autopoiesis

Children at first hung tightly to the allopoietic roles to which they were accustomed. Initially, the children often sought the researcher's approval and clarification of the task; as time passed children, more and more, set their own closure and judged their progress themselves. As the study progressed, the need for external criteria was replaced by the child's own preferences.

Oct.1, Tuesday

TR: . . . whatever shape you come up with is up to you as long as it's . . . start from a rectangle, and you can cut it, you know, you can paste it together . . .

B3: . . . Do you have to use all the paper?
TR: . . . You could use half the paper.
B1: Can you make an imaginary shape?

G1: Can I use my pieces again?
TR: Yes you can.

B1: Can we just cut out a shape and then add on?
TR: Ok, but remember . . . are you going to use all the paper?

TR: . . . It doesn't matter what it is so don't think there's anything particular . . . Remember it has to be flat , so it doesn't stay folded.

B2: Can you use it like this?
TR: Well no because that's folded.

B2: B3, you have to use all the paper.
B3: What do you listen to her for?

[A minor attempt to assert autonomy.]

B3: Does it have to be a shape?
TR: What could it be if it's not a shape?
B2: It could be a picture.

G3: TR, can I do this with that?
TR: Overlap them? OK you can but I'd much rather you made a shape edge to edge.

G1: . . . Can I do that?
TR: . . . it's a different shape, isn't it?
B3: See I did this shape.
B2: See my birdie.

TR: G1 has done two; she's made a triangle and I'm not sure what you would call that shape. . . .
B2: I'm going to make a birdie with fangs.

B2: Can you make a birdie with big fangs?

[Child/material systems largely allopoietic; external criteria sought through questions; self-organization doubted by child.]

Oct. 7, Monday

TR: Let me know what you start with.
B3: What about 3-dimensional?

G2: Could you show me what one's I've done wrong so I could fix them.
TR: Everything you've done is fine. There is no right or wrong.

B2: What am I suppose to make?
TR: Start with some shape . . .

B3: I like making shapes that look like nothing.
B1: You're allowed to do that?

[Allopoietic role illustrated by lack of confidence in one's own generative capabilities. Asks an external agent, i.e. the teacher, to judge products.]

Nov.15, Friday

I bring over B1's card to try- the one he says is no good.

(B1 has been making a tangram puzzle)
B1 finishes that one.
TR: Now are you going to do it a different way again?
B1: Yeah! . . . I'm going to cut out some pieces, you know like, let's see there was two big triangles in the pack, . . . then just move them all around and make some shapes.
TR: That sounds clever. I'll be old and grey before I solve this.
B1: See all those pieces are awful. (referring to his puzzle I am trying to solve.)

:

B1 is drawing shapes again . . .

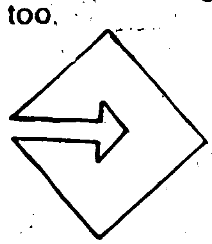
Nov. ~~22,~~ Friday

:

B3 is ready for me to trace his (shape). . . . . He decides this is all he'll do with these pieces 'cause the first one is really hard.
TR: OK!

:

G1: We never did that one (referring to a tangram card); I'm going to trace that one too.



G3: Oh my God, G1!
G1: Then I'm going to make new shapes. (She then asks G3 if she'll help her 'cause G3 makes good shapes . . .)

:

G1 tells me she's finished another set . . . She says something about an easier one (not quite audible). . .

:

G1: I don't know what kind of shapes I want. Can I get a square to start with?

:

I find two cards on the table as we're cleaning away.
G1: They're dumb, the shapes didn't fit, I had too many shapes.
(she wants them thrown away.)

:

[Child/material systems more autopoietic by utilizing internal criteria to determine closure; self-generation of system evident in production of ideas which produce further ideas manifested at times in actions.]

For the most part, in S3, the child/material systems were self-organized and self-referential. That is, children made decisions and created ideas from their interactions with the material which in turn changed the material. Techniques were still employed but in a more "artistic" way wherein choice was not "rote". Hence, autopoiesis was evident in the child/paper systems which emerged.

However, it is important to note that not only is it difficult to isolate the child/material system from the larger children/mathematics system in the S3 setting but on many occasions, children did not verbalize their experiences choosing instead to work silently, and alone. However, observations of the non-verbal activity still indicated that the child/material system evolved together; that is, the child did not blindly follow a series of steps to reach an end but rather ideas were generated as the experience grew. Initial attempts were often abandoned or restructured in order to compensate for the perturbations the child/material system experienced. B1, for instance, often fiddled with the paper pieces he had cut and made numerous different shapes which he never taped together. This continuous manipulation in response to the "material" was also evident in the tangram episodes where children arranged and rearranged pieces in the puzzles, without verbalizing their actions, until a solution was reached. There was also one episode where such child/material autopoiesis was overt.

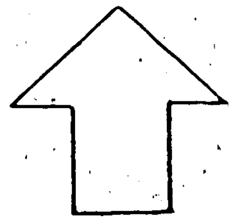
Nov. 7, Thursday

G1: G3, you didn't do it this way did you? Two triangles, that, that, that.
G3 shakes her head.
G1: (clears card) I'm going to do it with one bag.

G1(to me): Each time I do mine I have a triangle missing.
TR: That's funny 'cause the same thing happens to me.

I continue to suggest to G1.
TR: Put the square in the corner.
G1: Do this (meaning place two large triangles in the top to form one large triangle) and try to get a square out of the rest

of the pieces.



G1 works at the square; I watch.

[Ideas are generated from interactions within the child/material system; properties of material stimulate an idea which in turn stimulates action and so on.]

G1: Hey I did it! I just need to put it on . . . Oh no it wouldn't work 'cause it's not exactly square.
TR: And that was such a good idea. I see what you mean. It would overlap. . .
G1 makes a couple of turns of the square (to try and fit it). She removes a piece; she doesn't give up.

[Internal criteria used to judge actions and ideas.]

G1: I can't do it; do you (G2) want to help me?
G2 looks; G1 looks away briefly and then back.
G1: I get it!
G1 seems to be moving most of the pieces, but G2 makes some suggestions.

G1(responds to G3's inaudible comment): I did it but I'm trying to do it with one bag.

G1: I know, if I had that square again I could put it there, down to there and then put triangles on the end.

[Recursive activity used in self-organization of activity.]

G1 asks for help as I move away from G2.
TR: OK, let's see. You have your square-- you filled that in.

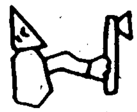
G1: Triangle doesn't fit; you have to use something else.

We fiddle with the pieces . . . we figure it out.

There were numerous episodes where a child's initial product served as a springboard for new ideas which led to an even more different end than first intended.

Oct. 23, Wednesday

B3 . . . couldn't make a snowflake; then said he'd made a mask; then he called it a Christmas tree, then a birdie's head . . .
B3 now shows off his "executioner", . . (Note: The head remained folded).

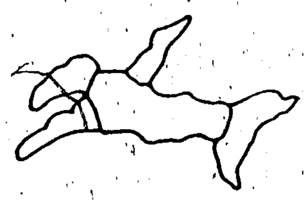


Oct. 24, Thursday

B1 makes a witch . . . B3 does his own cutting . . .
B1: I have a perfect witchie. There's her hat, her face, . . . , her broom.

B1: It's half bird, half witch.
TR: It does look like an eagle.

B1: There, there it's an eagle.

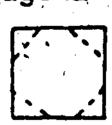


B1 gives up on his pieces to start something else. . . .
B1: I'm going to make a white witch.
TR: Maybe a white ghost with shredded clothes.
B2: A zombie.
B1: OK, I'll make a zombie. (B1 cuts zigzag shapes.)
B3 decides to use two colors.

B1: There's a zombie.

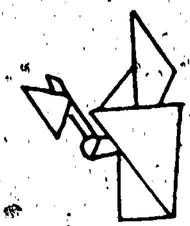
B3: I just cut out shapes and hope they'll turn out to be something.

G2 asks for help with a pumpkin. I suggest we need a triangle for the stem; I fold a triangle to cut off. Later, I fold 3 more triangles to get a hexagonal shape for the pumpkin.



G2 cuts off the triangles.

B3: See, look it, here's . . . Look it, here's a phantom. See, here's his hat, his head, his arms, . . . This guy's going to have a machine gun. . . (B3's phantom is similar to the "executioner" when it ends up with an axe, not a machine gun.)



G1: That's good G2.
G2 continues to add pieces until (I turn around)
TR: A pumpkin man!
G1: The Great Pumpkin!

[Initial conditions are not deterministic but rather lead to unpredictable conclusions. Child/material system perturbed by precursors, i.e. geometric paper constructions, and in turn generate more ideas.]

Nov. 4, Monday
(The first day for doing tangram puzzles.)

B1 decides to do another one (card) although he hasn't completed the first.
B2: It's the same.
B1: They're different.

B2: This is simple. I'm done.

B2 adds a piece not required and says he made a house. Then he builds a rectangle.

[Self-generation of child/material system evident in that the child's actions go beyond that required by overt external parameters of the material, i.e the actual tangram puzzle.]

Making personal decisions was also a prominent activity in the S3 setting. Child/material systems usually evolved as the child wished rather than as initially directed by the teacher or other peers. The children's interpretations of the "journey" concept as well as G1's independent decision to complete and copy the tangram cards to make her own sets are illustrative of developments which came from the relations between child and material.

Oct. 17, Thursday

TR: So what are you up to today?
B1: Adventures!
TR: Good, are you going to try to do another journey?
B1: Yes!

B1 shows me his shape he's made from the triangle; it's irregular; now he plans to go back to the triangle.

B1: I've gotten this so far.
TR: Good. What did you start with?
B1: Triangle.

B1: I think that went like that.
TR: Can you remember your other shape?
B1: I think.
TR: Could you draw it?
B1: Why?
TR: 'Cause how will I know?
B1: No, I can't
TR: OK! Well, you'll know you made a journey.

(On the previous day when B1 had done a "journey" he had cut, pasted a shape together, traced it, and cut the tracing to paste back into the original shape.)

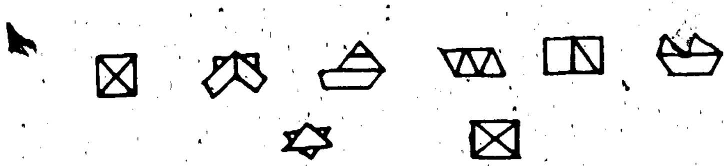
[Procedures used are generated by the child and are not copied from the teacher's methods.]

Oct. 21, Monday

(Earlier the girls had made journeys by using B1's technique of cutting, taping and re-cutting)

(After cutting two shapes from two triangles of the same shape and size)
G2: Since I've made 2 shapes from the same triangle, isn't it like a journey even though I didn't trace them?
I agree as long as she begins with the same triangle, she can call it a journey. So she decides to make more shapes.

G2: (explains to G3) I start from a triangle each time.



[Interaction with materials -influence direction generated by child; initial condition of "journey" leads to the use of different processes by individuals.]

Nov. 21, Thursday

G1: G2, would you help me make a shape? I'm not good at it. I got an idea. I'll use one from the box. (She heads to the corner to get a tangram set) . . .

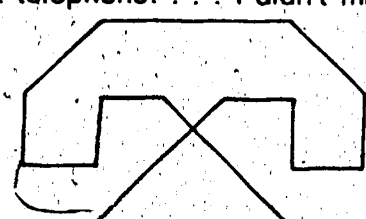
G1 offers G2 a card to try.
G2: With paper? Wait, maybe after.
G1: Do it with your shapes. . . .Oh you haven't got that kind (of shapes), I forgot.

. . . G1 is trying to complete a tangram card; she has already completed one and traced it onto her own paper.
(G1 adopts the strategy of completing a card with the "plastic" tangram pieces, rebuilding it with her "paper" pieces, and tracing a card for her set.)

[Self-oraganization and self generation of child/material system wherein ideas emerge from the activity itself, not from preset rules or external parameters.]

Nov.22, Friday
(G1 voluntarily explains to TR why she copied tangram cards)

G1: Mine is a telephone. . . . I didn't make it up though.



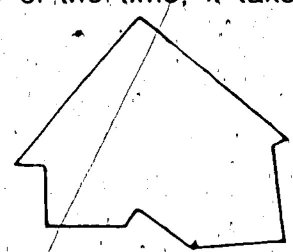
TR: Oh it was on one of the cards. . . .
G1: This is my last one with the cards now.
TR: Oh? OK.
G1: 'Cause I got bored of making them (her own designs) up.
TR: Oh, . . . So you took a rest from it for awhile, hey?
G1: Yeah!

Nov. 25, Monday

(Girls have been filling in tangram cards, then arranging the pieces to trace and make their own cards.)

. . . G2 says she just needs to make one more shape. G3 asks about the time . . . Five minutes remain . . . G2 rushes; she wants to do one more. . .

G2 asks for help with tracing . . .
G1 (to G2): Did you make it up?
G2: Yes, 'cause of the time; it takes too long to get the other shapes.



[External parameter of time interpreted as a perturbation which is in turn compensated for through self-organization of the child/material system, i.e. make my own shape.]

Thus, children enter into a coherent experience with the "paper" so that the paper task and they join to generate the possible events which emerge. Each child uses ideas to generate further ideas; they are stimulated by the potential of the paper and with the paper, they form an autopoietic system. Creativity is present; child/paper systems are self-referential in that the external observer does not play a major role in determining the evolution of the task. In the S3 setting, then, individual autopoiesis was released.

Social Autopoietic Systems

Social autopoiesis entails a composite of autopoietic components which as a coherent system generate the system in an ongoing development toward higher coherence. Individuals come together in a unit and through interactions and communication, the unit itself evolves. Within the three contexts observed in this study, the opportunities for autopoietic units to come together to form an autopoietic social system varied. Reciprocity or Maruyama's "mutual causality" played a large part in permitting the "coming together" to emerge as an autopoietic event.

The social autopoietic systems examined in this section involved child(ren)/child(ren)/material systems and teacher/child(ren)/material systems. That is, social systems, in which children interacted with children, a child interacted with another child, a teacher interacted with children or a teacher interacted with a child regarding the materials at hand, were analysed within the three settings for the presence or absence of social autopoiesis.

S1a and S1b - Social Autopoiesis

In the regular classroom setting (S1), most of the tasks assigned were done so on a whole group basis wherein children worked independently. When "group work" was organized formally, there were occasions which, for the most part, were allopoietic and there were others which exhibited autopoiesis. That is, at times when the setting involved children working in small groups or pairs, the interactions were restricted in such a way that self-generative experiences were inhibited. Instead, children completed the assigned task independently and then shared it with others in the group but did not use the group context to "build" the task together.

Sept. 26, Thursday

(T1 has handed out a list of Indian-Picture Writing Symbols)
T1: Let you write a message to a friend.
They get excited.
T1: If there's order. Sit quietly please.
The children talk about the sheets to each other . . . T1 quiets them and then goes through each sign orally.

They are to start but there's noise so T1 draws them back.

B6 makes up a quick one,(i.e. message); he shows it to B15 who passes it to B12. . . . B8 is excited about sharing his with B16.

(Children quietly make up messages at their own desk, then carry it to their partner and exchange).

[Potential social autopoiesis is overridden by the structure of the class i.e."work alone"; spontaneous dialogue between children is hampered by restrictions.]

Oct.18, Friday

Social studies in the library today . . . all very quiet. Each two students shared a book on Indians. Some wrote, others seemed unsure. T2 tried to encourage "team work" but the children didn't seem convinced. (There was little discussion.) Towards the end the boys became more talkative . . . they chatted about grizzlys . . .

[Social autopoiesis - i.e. team work - encouraged at the surface level; yet children choose allopoietic role of "getting the job done."]

Yet on other occasions, the small group activity was such that children did generate ideas which through further interactions "built" the experiences of the group.

Oct.24, Thursday

Last period . . . Science . . . T1 has set up stations (with the necessary equipment). T1 explains expectations and logistics. (The experiment is on sound and one section requires the child to blow into a straw and then cut the straw to see how length alters pitch.) The children are blowing in the straws; (it's noisy and most seem to stay at this rather than doing other sections of the experiment). T1 calls it fooling around. . . . B8 voluntarily explains to B15 how to blow into the straw correctly. B12 comes along and demonstrates the procedure to me. . . . T1 asks them to return to their desks . . . they disobey and continue with the experiment. . . T1 is about to erase their names from the "quiet workers" board, when they comply.

[Spontaneous coming together of children to share ideas dissipates into information transfer.]

Oct. 28, Monday

. . . T1 gives them the last period to work on their skits for the Hallowe'en party. G2 asks me to watch her group's play; I sit to watch. . . . they develop it as they act. (They discuss next action as they are performing.) They're not happy with it. T1 suggests they need to write it out, but they don't think so. They alter the scene again.

[Child/child social interaction leads to the generation of ideas and experiences.]

When the teacher also chose to interact with such small groups, the resulting interactions tended to be allopoietic in that the communication was not reciprocal. In general, the teacher monitored the group's progress and provided feedback, or answered questions rather than pursuing discussions with the group members. Therefore, although the teacher "physically" entered the group setting, the teacher's membership was incomplete.

Nov. 4, Monday

Science . . . last period . . . T1 chooses groups of three and hands out the equipment. They work in an area around the classroom. Two groups of girls seated near each other join together . . .T1 reminds them not to waste time with the straws.

B6 comes over to TR, reads a paragraph on the sheet; then asks if TR understood it . . . He asked if I would help. I agree. He began to answer questions on the sheet; he didn't look at the equipment.
TR: Aren't you going to do the experiment?
B6: After, first I'll do the sheet 'cause when I do it in the other order, I never get the sheet finished.
Once I explained (the terms) he answered each question without difficulty; the questions referred to previous experiments, except the one about the test tubes which he likened to the beaker experiment.

Nov. 13, Wednesday
Social Studies . . . (they're to write an essay on a field trip). . .

B1 and then B6 ask for the name of the house where the things were hung up . . . T2 answers . . . Others question T2 on the details of the trip. . . . B2 is concerned about the length and B3 checks to see if T2 meant one page double spaced. . . .
B1: How many trappers in the Factor's house?

B3: What was in the barrels?
Several children answer B3 with rum, wine. . . .

T2 mentions the Factor's two daughters when G9 inquired about the rooms.
They work individually . . . Towards the end, B7 turns around and he and B17 play "poison darts" with the tubes of their

pens. When T2 catches them, B7 asks a question.

:

[Teacher/child interaction not mutual causal per se; more an information transfer than a dialogue. Search for "the answers" a major constraint.]

However, there were occasions, usually during "whole class" discussions of social studies topics, whereby the teacher/children interactions were generative. In this context, teacher's and children's ideas were mutually received and served as precursors for further ideas.

Oct. 8, Tuesday

They read together . . . stop to discuss.
T2: What did the Indians take advantage of?
B1: White man (pause) guns gave advantage against other tribes.
B3: So they can fight.
B2's imagination is sparked . . . machine guns , war, . . .
T2: But what's the advantage of guns?
B7: Greater advantage to defeat.
B3: Was it rapid discharge?
B1: Greater chance of surviving; they can push other Indians off their land.

:

T2: We've talked of war but what good things could guns be used for?
B1: Hunt.
B2 draws and shares picture with B6.
B1 (reconsiders): Gun would scare animals off when you shoot one, so you wouldn't necessarily get more.
T2: Good point, but with the accuracy of the gun you wouldn't have to get so close..
B2: They could hide behind a bush.
B3: The arrow might just stick in rather than kill.
B11: You might have to hit it in the heart.
B1: How would they know how to take the bullet out?
T2: They watch the white man.

:

They talk of killing animals for food and warmth. Someone asks why don't bears kill man to get warm?
T2: Bears don't have brains.
One of the boys: Coyotes do.

:

Oct. 30, Monday

:

Social studies . . . (T2 asks questions to individual children) ...
B7(initiates a question): What if the Cree kept the fur?
B1: War!

T2 agrees and asks next question -suggests they check hand-out for a French word.
B1: Rendevous.
B2: What is a rendevous? I thought it was when a man met . . .
T2: That's what Indians did was meet. . . . What did they do when they met?
B1: Peace pipe
B3: Celebrate
B1: Party
B3: Joust

T2 now directs it (questions) toward others

B3: What if the Indian has no family?
T2: They'd be made to care for their grandmother or an elder.
B7 asks another question which leads to talk about individual sharing food. . .
G1 is yawning. G2 and G3 are quiet . . . B2 and B6 are drawing and chatting . . . B1 and B3 are attentive . . .

[Children's ideas serve as precursors for the teacher and vice versa. A reciprocal dialogue ensues; a self-generating conversation.]

Likewise, in similar discussions the teacher remained on the periphery while children generated their own ideas, sparked by the mutual comments of other children. The teacher "policed" the evolution but did not participate as such in the discussion.

Oct. 4, Friday

. . . they listen to some of the children read their legends . . . Children are very quiet. G4's story of "how buffaloes got horns" stimulates discussion and B2 and B6 each extend it further, using their own explanations. G1 mentions porcupines shooting their quills which leads to arguments among some children.
A child: They don't shoot quills!
B3: Quills are loose and when they rub up against something they fall off.

(T1 permits these interruptions between stories; but does not respond to them.)

[Children's ideas serve as precursors for other children; indirect interactions between children lead to generative dialogues.]

In contrast to such events, there were also episodes where children attempted to interact and collaborate, but the teacher "cuts" the generative activity short)

> Oct. 3, Thursday
>
> T1 talks to the children about legends; T1 gets them ready to begin by soliciting examples of possible questions, i.e. suggested topics. B1 is then requested to retell what they are to do . . . they are permitted to start. Immediately many small discussions break out- children chat to friends about possible stories . . .
> T1: Are there any questions? No, well, we've already discussed it. Do your own story quietly.
>
> [Spontaneous child/child dialogue unable to evolve due to external parameters.]
>
> Nov. 7, Thursday
>
> (Children are writing diary entries as assigned on the previous day. B2 decides to include a map.)
>
> B2 is drawing a map, B6 watches and asks questions about symbols . . . T2 tells him to put it away . . . T1 encourages B6 to work.
>
> B6 shares ideas with B2 who responds that an explorer would not hunt. . . .B6 starts a story . . . T2 tries to get B2 back to work.
>
> [Potential for child/child social autopoiesis dissipates due to restrictions of environment.]

Hence, it was evident that most teacher-children interactions were hierarchial wherein the teacher "policed" the "joining together" of individuals. Reciprocity whereby the child-teacher conversations were self-generative was seldom observed. For the most part, teachers maintained a central position at the front of the class and when they did circulate, interactions entailed monitoring children's progress and relaying information. Dialogue which amplified the generation of spontaneous ideas was mostly limited to child/child interactions, although some discussion episodes resulted in the teacher's participation in such autopoietic units. Thus, social autopoiesis was not totally inhibited and was sometimes released in the less structured atmosphere. Otherwise, interactions were so restricted that dialogue as such was overshadowed by the transmission and recording of information

S2 - Social Autopoiesis

In the regular small group (S2), proximity encouraged interaction between the children in a more informal atmosphere, yet much of what happened did not appear autopoietic. Children conversed on personal topics while they worked but seldom provided impetus for one another with respect to the mathematics. The group did not seem particularly coherent; sharing ideas or products was not a major component. When the girls at times worked together, it was mostly to check answers; I seldom observed instances where children suggested processes to aid each other. For the most part each child worked alone. On only one occasion were children directed to work together and this occurred near the end of the study. In this instance, the researcher asked an "early finisher" to help another child complete his work. However, the child/child exchange which resulted was highly allopoietic since one child instructed the other.

Nov. 26, Tuesday

TR hands out worksheets (multiplication/addition principle)

TR: First example, three rows of five; I want ~~to divide~~ in two parts. . . . and describe your parts.
G1: Always keep threes
TR: No you must keep your
B1: Fives
TR: What's written in words.
They begin . . .

I suggest to B3 that he help B2 so B2 can finish.
B2: Can you help me B3?
B3: OK, 7 groups of eight is the same as; put 7 groups like into. two groups.
B2: I don't know times.
B3: 4 groups, go 4
B2: Where?
B3: There in that space, 4.

B2: Three
B3: Just put things that add up to 8, to 7!
B2: Oh, OK!
B3: And it has to be 2 things; like 5 and 2 and 1 and 6.

B3: In that box (he points) 5 times 8 and then 2; no not in both boxes, and then 2 times 8 right there.
B2: 2 times 8

B3: 5 x 8 is 40
B2: What's this?
B3: That's 16
B2: No what does this one; I don't get it.
B3: Put 1, 1x8, then 6x8 and that's the same.
B2: Oh, 56?
B3: Yeah

[Child/child interaction unidirectional for the most part; non generative. Child follows directions given by another; thus social allopoiesis dominant.]

On the other hand, in another session towards the end of the study, the two boys present chose spontaneously to work together on an assigned task. In this instance, social autopoiesis emerged as the children presented ideas to each other and thereby generated further ideas which eventually led to a solution.

Nov. 19, Tuesday

B3 begins to quiz B1 on an exercise in text . . . B1 assigns one to B3 . . .
TR: That's not what I meant though; is it what you want to do?
B1 and B3: Yes!
I ask the girls if they want to ask each other . . . the boys have no difficulty . . . G1 suggests to G2 to use the clock to get an answer . . . later G1 suggests to G3 to count by fives to get the answer . . .

Boys jump ahead to another page . . . (I intercede and review orally with them all the concept of multiples). . . I assign some exercises . . .

I assign the Braintickler . . . I explain a little of what is wanted . . . whatever number, I get a two digit answer.
B3: 5 x 2
B1: When you times two of the same number
B3: 1 x 10
B1: No it has to be a single digit; see, single, single, double.
B1: I ~~got it;~~ oh man I'm so smart.
B3: What is it , 3?

B1: 5 (He comes to tell me; I tell him there's two answers and suggest they try to find the other.)
B3: 10 x 10 . . . 20 . . . it's 100. Oh yeah!
B3: 6 x 6
B1: Yeah, we got the answer.
B3: (to me) We got it.
I now assign it to the girls . . .

[Dialogue is generative in that one child's guesses serve as precusors for another; ideas are generated within the social system.]

In the S2 setting, most of the teacher/children interactions were unidirectional and included the assignment of exercises or the provision of instruction. On some occasions, the teacher and children did engage in discussions of the concept or topic. For the most part, the discussions were structured by the teacher's questions, but in a latter session, autopoiesis did emerge to a certain extent in that children's spontaneous ideas were incorporated into the development of the discussion.

Nov. 21, Thursday
. . .We orally discuss even and odd numbers .
TR: Who can tell me what an even number is?

:

TR: No not an example but what it is.

:

B3: It's a number you can split
TR: What do you mean by split?
B1: Split evenly.
B3: Like 6, 3 and 3.
B1: You can divide it in half.
TR: . . . What's an odd number?

:

B1: It's a number you can't divide by 2.
TR: It's 1, 3, ..., 9, like that . . . Can you put two into five and get something out?
B3: Yeah.

:

TR: Not in five, well it's a decimal.
B3; You can divide.
TR: You have something left over.
G1: That's like the worksheets you did with me.
I don't understand what she means so she shows me the division sheets they had been given early in the term when I was observing the class.

:

TR: . . . Is 152 even or odd?
B1: I know.
B2: Even.

TR: Even, is he right?
B1: Yeah!
TR: G1, is 327 even or odd?
:
G1: Even.
TR: Even she thinks.
B1: Odd
TR: How do you know?
B1: Because it's a seven.
TR: It's because of the seven. Where was the 7 in 327?
B1: Last one.
(I elaborate) . . . other examples are given and clarification continues . . .
TR: . . . B3 is going to give us what, an odd number?
:
B3: 55 000 and 600
B1: I can give a large number
B3: So can I.
TR: We're still waiting for this one.
B3: and 15.
TR: 55 615 is that odd?
:
B1: I can give you an even number
:
B3: One million
B1: No, one quintillion
TR: It's going to be hard to follow.
B1: three billion
:
B1: 362 thousand, 428.
TR: Is it even?
G1 : Yes!
We proceed to the next exercise which involves products of even numbers . . .
TR: Give me two even numbers and the answer.
B1: Times?
TR: Yeah
B1: 2 x 2
TR: is
B1: 4.
I ask others for examples . . . I acknowledge B1's hand.
B1: 10 x 5
TR: 10 x 5 is what? Is that even times a . . .
B1: 10 x 5 would be one.
TR: Is 10 even?
B1: Yeah
TR: Is 5 even?
B1: No
TR: So you're talking even times odd now.
B1: Yeah, but it ends in zero
TR: Yeah so it ends up being an even
I ask for further examples . . . assign text exercises . . .
:

[Questions were generated from the conversation somewhat; however structure did not allow maximum social autopoiesis.

Limited individual creativity permitted.]

In such a small group setting, much of the teacher's interactions with the children was on a one-to-one basis. Overall, however, these interactions usually arose when a child requested help with a particular exercise and the conversation consisted mainly of suggested techniques or possible paths a child might follow. Although, instruction was not given dogmatically, it was usually unidirectional.

In essence, then, social autopoiesis was minimal in this setting. Although mutual causal interactions were encouraged in that children were never told to work alone or to work quietly, child/child interactions and teacher/child interactions were overly influenced by the need to ascertain particular techniques to complete an answer correctly. The organization of the social contexts was largely determined by these external motivations and did not evolve per se.

S3 - Social Autopoiesis

In the enrichment small group (S3), proximity and informality were major characteristics also but the interactions in this setting were much more spontaneous and relaxed. Children still chatted but also much of their interactions dealt with the task at hand. Here children lent support, provided suggestions and shared processes. Similar interactions were also observed between teacher and child, especially when the teacher was participating in the task rather than monitoring the children's progress. Reciprocity was evident here and the groups as systems were often autopoietic.

The child/child systems usually involved two or three children who spontaneously chose to interact. Their "coming together" and the group's subsequent dissolution were totally dependent on the children involved.

Nov, 6, Wednesday

G2:Look, look, look! (G1 does and they laugh)
G1 now reaches over for pieces and starts putting them in G2's shape. When G2 goes to make a move, G1 tells her she can't do it.

G1: Here, use this.

G1 and G2: Yes, Yes!
G2: Where do you put this?
G1: That goes on the other side, right here.
They continue to add pieces.

G1: I know, I know. . . I mean
G2 picks up a piece: I'm going to do it myself.

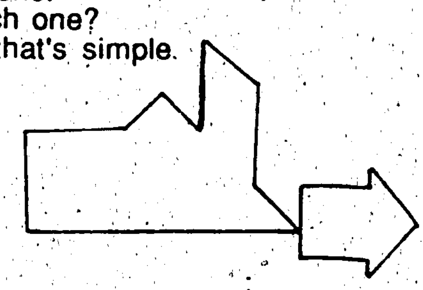
G1 won't give up.
G2: But they're sticking out, G1!
G2 takes command. G1 returns to her own card and turns it over.
G2 (starts again on hers): Oh, yes they are. Now let me do it myself.

[Opening and closing of the boundaries determined by the members of the system. Child/child systems spontaneously emerge and dissipate.]

Thus, children moved freely in and out of "groups" as they worked on the tasks at hand. At times, these child/child interactions involved one child instructing another child so that rather than children's ideas complementing one another, one child followed the directions given. In this sense, such social experiences were allopoietic.

Nov. 5, Tuesday

G2: I don't get this!
TR: Keep at it 'cause B2 did that one yesterday, so I know it can be done.
B3: Which one?
B2: Oh that's simple.

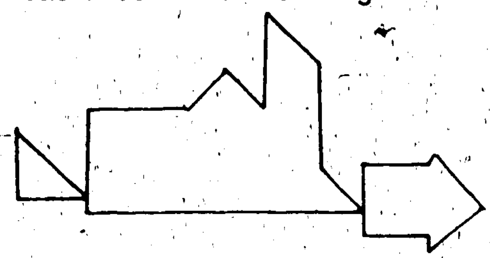


B2: You have to use both bags,G2.

B2 goes over and begins to give suggestions (as to what pieces to place where; G2 listens and watches). . .

:

(As B2 leaves G2,) B2: When you do that one, there's a simple one on the back. It's the same thing but one things added to it.



[Child chooses when to enter and leave a dialogue; thus, boundary of social system flexible.]

Nov. 7, Thursday

:

B3: Are swans easy or hard B2? Are they hard to do?
B2: No they're not.

:

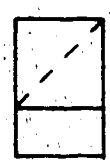
B3: How'd you do them?
B2: It's like this, watch. (Cuts a smaller square, starts folding; B3 watches and toys with tangram)
B3: Do they have to be squares?
B2: Yeah!
B3: I got some awesome square paper . . .

:

B3: OK, how do you make them? (he takes a sheet of paper)
B2: First, you need a square.

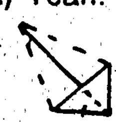
:

B2: Go into a square, right?
B3: Any size?
B2: Yeah any size as long as it's not too small.
B3 was going to cut; he sees B2 fold so he folds his before cutting.



:

B2: Fold it in, sides like that.
B3: Kinda like a kite?
B2: No. (stands to look) Yeah!



:

B2 and B3 continue on swan. (B2 demonstrates each step.). . .
B2 and B3 finish swans . . . B2 tries to encourage B3 to make a

small one from the leftover paper. B3 instead turns to the tangrams.

B2 goes over to get a set of tangrams too.

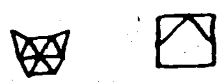
[Common interest generates a social system. However, since one child directs the other, conversation is somewhat unidirectional.]

In other episodes, there was less instruction and a child observed another's actions and either carried through with a similar task or altered the task in some way, sometimes to be different and sometimes to avoid conflict.

Oct. 22, Tuesday

G2 : G3, what're you doing?
G3: A shape!
G2: You know what I'm doing? I'm cutting the rectangle then taping it, then I'll cut other shapes.
G3: Do you have to do that?
G2: No, but I've already done one.
G1: I made a cat face.

G1: (to G3) I've made two things, that's not too bad.



G3: How about getting it back? (moves hands in a mixing notion)

G2: Can I use it (the rectangle she had cut and taped together) as the last step in my journey?
TR: OK!

G3: Are you doing a journey?
G1: I made a cat face.

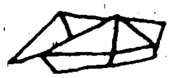
G2 has cut a lot of small shapes; she asks for help deciding what to do. I start arranging then she adds one; I ask her where I should put the next . . . she asks for help to tape it.

G1: Is that your journey?
G3: No! Are you going to make a journey?
G1: I am
G3: You don't have to trace it.
G1: Yes you do.
G3: No I'm just starting with the same thing
G1: You are?

G3: I'm going to ask her what to do . . .
B3: I'm doing a journey, TR. I just did part of my journey.
TR: Could you draw it?
B3: No!
TR: I'll be right there.

G1: Is it okay if I make something, trace it and start from that.
TR: Yes it is.

G3: Can I do this?
TR: Yes, you certainly can.Are you doing a journey too? Good!
G3: Yeah, I'm doing what G2 did.
TR: Yeah, you're not tracing it, you're doing it.



[Child/child social systems emerge such that discussion/revelation of one child's actions serve as perturbations for others in the system.]

Oct. 28, Monday

The children are taping their figures to the background (to create the Hallowe'en mural).

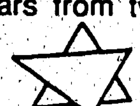
B3: My wizard's going to be flying in the air.
B2: Oh, B3, I'm going to make mv wizard fly in the air.
B3: You can't! Oh, B2's copying.
B2: I'm not copying, B3!

B2: B1, I'll make my wizard surfing.

B1 suggests a jet skateboard to B2. G3 wants to make stars. . .
B2: (has two triangles) There's his head; I made his arm. Ha, Ha, I made his arm.
TR: Excellent.

B3 is still adding to the wizard.
TR: Don't overdo it; make some new things.
B2: I'm going to make a wizard skateboarding.

G2 (to G3): Make stars from two triangles . . .(overlapping)

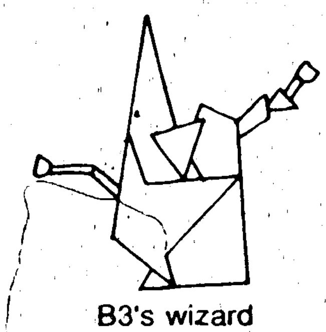


G3 makes a star from 4 triangles.

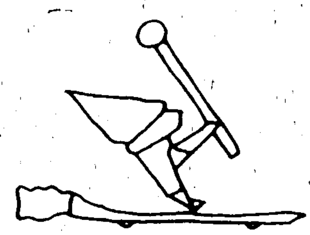
G3: Is that a star?
TR: You know what, it looks like a flower, we could put it on the grave. . . . I ask G3 to help me cut some triangles to make my skeleton ; any shape.

B3: B2 is just cutting out shapes he needs; not using triangles and stuff like I did.
B2: I am.

Recess . . . B2 decides to stay and finish. The girls - G1 in particular show her shapes to some of the girls from class who come over . . .



B3's wizard



B2's wizard

[Intial conditions i.e. same precursor leads to different products as children attempt to be different from the other; to assert personal autonomy to a certain degree.]

On other occasions a child directly manipulated the task of another. In these interactions, children sometimes adopted the change and continued from there while at other times, they chose to ignore the change and go another route.

Nov. 6, Wednesday

G2: Look, look, look! (G1 does and they laugh)
G1 now reaches over for pieces and starts putting them in G2's shape. When G2 goes to make a move, G1 tells her she can't do it.

G1: Here, use this.

G1 and G2: Yes, Yes!
G2: Where do you put this?
G1: That goes on the other side, right here.
They continue to add pieces.

G1: I know, I know. . . I mean
G2 picks up a piece: I'm going to do it myself.

G1 won't give up.
G2: But they're sticking out, G1!
G2 takes command. G1 returns to her own card and turns it over.
G2 starts again on hers: Oh yes, they are. Now let me do it myself.

G2: G3 you can do this one. (G3 was taking another card.)
G1: I'm doing that one. (G1 takes one G2 was doing.)
G2: I want to get a different one. (She takes the one G3 had finished)
G3: You saw me do it.
G2: ~~I did~~ not. Ok, I'm going to do it right now.

G2: I have two triangles left. (She means two triangular spaces) G3, can I use two of your triangles?
G3 refuses. We laugh.

Now G3 offers advice and takes out a piece, inserts another for G2. She moves away, G2 tries to solve it.

[Within social system, i.e. child/child/material system, child permits other child to impose certain ideas but only to a certain limit. Based on internal criteria, individual autonomy is asserted and suggestions are perceived as perturbations rather than input. Compensations are made to maintain child's identity.]

Nov. 21, Thursday

G1: Those are your pieces?
G3: Yeah.
G1: Here go like this! I had something done . . . no.
G1: Are you going to make another set?
G1: If you bring this over it'll look better. If you move this a bit over so it . . . like that.
G1 and G3: That's a parallellogram!
G1: Or you could make it a tangram, if you turn that; not a tangram, a trapezoid.
G3: Yeah, I'll do it that way.
G1 returns to hers. . . .

[Spontaneous development of child/child system results in somewhat "unidirectional" dialogue, yet the intent did not seem to be to impose. Ideas were accepted in a mutual sense.]

Children's interactions in this setting also entailed the regulation and encouragement of one another's actions. These interactions would correspond somewhat to Maruyama's deviation counteraction and deviation amplification processes.

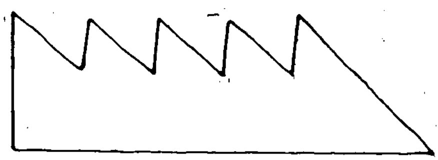
Nov. 6, Thursday

:

G3 starts another (tangram card) after completing one . . .
G3: I give up on this thing.
G1 and G2 rally to her support. They had trouble too with it. I rise to help her too.

:

G1 and G2 : When B2 gave it to us, we couldn't do it either.
G1 watches; G2 works at her own; G3 and I work away at it.



:

[Positive feedback supplied by children to amplify another child's actions.]

Nov. 25, Monday

:

B3: I made two sets B2! You haven't made any.
B2: Yeah, really?.
B3: You haven't made any sets.
B2: Yeah, well look.

:

B2 is counting out his puzzles to B3.
B3: It's not sets, 'cause you have to have more than one card with the pieces.

:

[Deviation countering process employed by one child to regulate actions of another.]

Nov. 27, Wednesday

:

G2: Are you tracing those shapes again? (the plastic tangram pieces)
G1: Should I?
G2: No don't, 'cause you made some. Well I've traced those shapes . . .
They pause as they try to decide how to make new cards . . .

:

G1: Using those again! (refers to the tangram pieces)
G2: What? Those?
G1: No those.
G2: No I'm only going to use 2 or 3 of them.

:

[Deviation countering of other's intent.]

G1: Those shapes are strange.
G2: (laughs) And you can't make them.
G1: I'm using the parallelogram
G2: I'm using . . . I need the parallella . . .

:

G2: Give me a parallella; I'll use a big one

:

G2: a triangle . . . That's all 'cause then it's more easier.

:

G2: And I'm going to use this big one . . . this little one, that one, that . . . just want a big one (triangle)
G1: You've used them all except one.
G2 tosses a piece back . . .
G3: G1, are you using them again?
G2: No we just do the four and there's seven . . . We're just going to do four of them

:

[Deviation amplification occurs as one child's choices amplifies the actions of another.]

Children also grouped themselves spontaneously to discuss ideas they had or approaches they were planning. That is, they reflected on one another's activities as well as their own.

Nov. 6, Wednesday

:

G1: (excited) I did it! (She completes a tangram puzzle)
G2(moves quickly to try and catch it before G1 clears the card): Don't wreck it. Don't wreck it. (She tries to pick out the pieces G1 used).
G1: Oh G2 is going to copy shapes (laughs) (Clears card)
G2: Oh, G1! OK, let me make it. Just wait. (She exchanges her card with G1).

:

G2: See G1, this is how you put this one here. (G1 is doing her own; she glances)
G1: You did it an easier way. I didn't know that.
G2: Well I thought that's how you did it.
G1: I did it a harder way.
G3: I did it that way too.
G1: I did it but it wouldn't work for me.
G2: See I made it.
G1: I put a square there and a triangle there and a parallela here

:

G2: Did you do this one?
TR: I did but it took me a while.
G2 gets it quickly.
G2: It's not with one set.
TR: It is different from my solution.

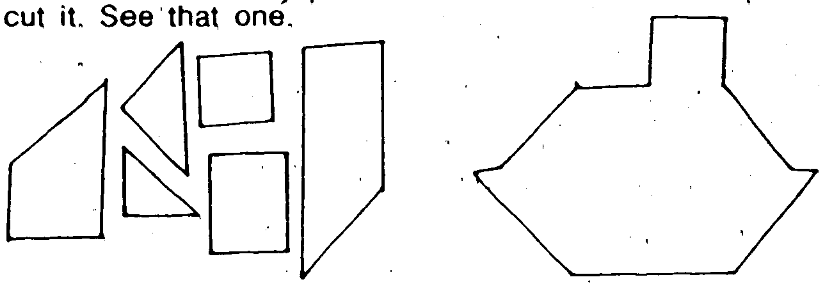
:

[Child/child/material system self-generative in that ideas produced lead to production of more ideas, i.e. the idea of "different way" led to more "different ways".]

Nov. 21, Thursday

B2 returns to table, still folding an airplane.
G1: I make dumb shapes; G3 makes good shapes.
B2: I know 'cause she uses a ruler.
G3: No I don't.
B2: Oh you call that not a ruler
G3: No.
G1: No, she uses her shapes. Her shapes are good line shapes, not this.
B2: That's what she used.

G3: 'Cause one of my pieces on the bottom was a square 'cause I cut it. See that one.

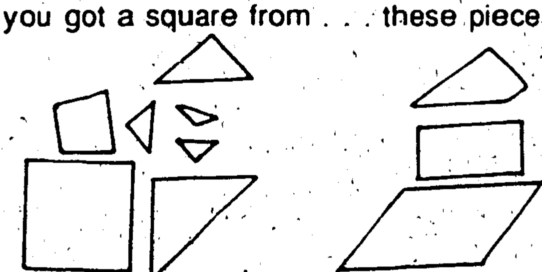


[Child/child/material system such that actions of one reflected upon by the other.]

The teacher/child interactions were often spontaneous as well and emerged from the event rather than being preplanned as part of the "lesson". Sometimes, a child's request was the precursor for the "coming together" while at other times, the teacher initiated the dialogue.

Nov. 18, Monday

G1: TR, can you find out how I got a square from these, because I don't know how to do it.
TR: How you got a square from . . . these pieces you mean. . . .



G1: I cut those pieces off there.
TR: OK, so that was like that, do you think?

:

TR: OK, this one looks like it was over there, on one of those sides . . . that looks like the bottom part of the square . . .

:

G1: But

:

TR: Does it fit like anything? No, this won't fit in here, does it?
G1: This is a piece for it (holds square) That's the same.
TR: That's the same size . . .
G1: I don't think it was in there.
TR: Oh wasn't it sort of in the centre?

:

TR: OK now how did we get our parallellogram? (G1 makes a move) Oh that looks right. . . .

:

G1: This one goes there . . . got to make a triangle.

:

TR: . . . If we can get a triangle out of that we know we got it.

:

TR: You got it. Little piece in there looks good, square right there, looks good, . . .
G1: Then there's all those to make a triangle.

:

G1: Maybe I got this part all wrong?
TR: Maybe.
G1: It would work any way I did it.
TR: Right, so it's just a matter of
G1: What about if I made that . . .
TR: That's right, that's right! That might be just as easy. But then , no that wouldn't fit in there. . . .
G1: That's better.
TR: I think so.

:

G1: That
TR: fits there
G1: Yes
TR: And that definitely fits there. . . So this should fit . . . supposing it was there like that . . .

:

G1: Oh I see it.
TR: Do you see it? . . . And then we can put this back down there. So we got it : ...

:

[Child initiated dialogue leads to spontaneous emergence of child/teacher system which is autopoietic. Mutual reciprocity at the core of conversation and ideas generated internally by components of the system.]

When the teacher participated in the assigned activity, similar to the children, children would often initiate the dialogues and proceed to offer ideas to the teacher as they would to a peer.

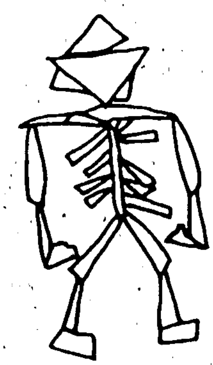
Oct, 29, Tuesday

We are making our own small murals . . .I begin to make a skeleton (I've folded some triangle shapes of different sizes).

B2: That's a skeleton? Look B3.
B3: A funny skeleton.
B1: What's that?
TR: His shoulders.
B2: Don't you know what a skeleton looks like . . .

G1: Use the large triangle for his head and use the others somewhere else.
TR: Good idea!

G3: She finished her skeleton.
G2: Did you tape it.
TR: No
B3: It's crazy; it's got a big head.



[Children/teacher material system such that chidren provide perturbations for the teacher; spontaneous mutual dialogue occurs.]

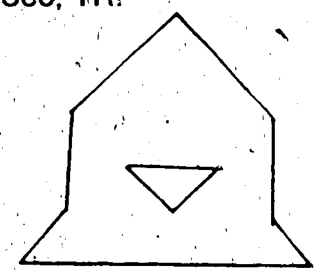
Nov. 5, Tuesday

TR: I can't seem to get this one done. (refers to a tangram card)
B3: I can't seem to get this one either.
B1: I got this one.
B2: I can't seem to get this one either. (to TR) Oh that's simple, I can do that one.
TR: With one bag?
B2: Yeah.
B3: I did that one, it was easy.
TR: With one bag. OK, I got to try and figure it out.
B2: Here, I'll show you.
TR: OK, just give me a minute . . .

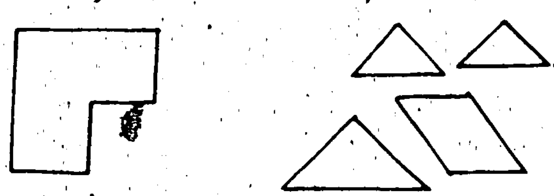
B2: It won't go anywhere.
B1: Those big ones (triangles) practically don't go anywhere.
B2 looks for another card.
TR: Do you know how to do it, B2, to show me?
B2: I never did it but I could probably make it anyway.
TR: You sure you did it with just one bag, B3?
B3: Yeah, I have to find it and show you I did it.

TR: Oh, I got it! Alright I got it with one bag!

TR struggles with another card.
B2: Here let me show you.
TR: OK, Show me.
B2 begins to try to put it together. G3 and I watch. G1 comes over with hers . . . shows G3, waits . . . I'm watching B2 so G1 returns to her spot.
B3: I did this yesterday but I can't seem to do it.
B2: I think I need one more piece .
B1: I did it! . . . See, TR!



TR: Oh you did, it sort of looks like a rocket, B1.
B3: Oh I did that one . . .
B2: You're suppose to fill up the space.
TR (to B2): We're suppose to do my puzzle with 4 pieces. (B2 continues to try and work it out.)



B2: I can't get it. (B2 tries another idea.)

B2: Let's check the back to see if there's a similar one we might work out. (There isn't one there . G2 looks over.)
G2: I did that one.
TR: I'm having trouble with it.
G2: You just use
TR: Just these four
G2 walks over . . .
B2: Can't do it.
G2: Put a square there.
TR: Oh no that's not . . . B2 said he did it too. Got any ideas?

TR: Somewhere this has to fit and it's so big. (refers to the larger triangle)
G2: It can come right here at this corner . (She leaves and asks G1 for help with hers.)

TR: I think I've got it. . . . Thanks B2.

TR: OK, I figured it out.

[Indirect actions and comments of members of the system serve as "kicks" for other members. No effort to direct the ideas of the other, but rather the atmosphere is such that comments or actions of members serve as important "triggers" for the ideas and actions of other members.]

During the occasions where the teacher initiated the interactions, a variety of approaches evolved. Sometimes there was direct instruction, while on other occasions, the teacher assisted the child or shared ideas, and in other instances, she simply provided commentary.

Oct. 3, Thursday

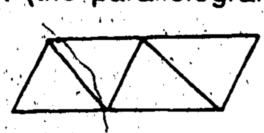
B1 sizes up his shape, says it's a pyramid on its side. I agree it's an irregular shape. B1 starts counting sides. . . .

B2 cuts out a snowflake.
TR: I thought you were going to use pieces.
B3: Anybody could do that.

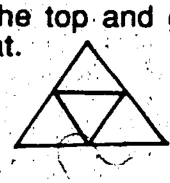
G2 plans to make a cross from two rectangles.
TR: They'll overlap.
G2: So?
TR: It's OK for now, but you might want to think how you could do it without overlapping.

When G3 asks for a suggestion I remind her of the parallellogram G2 made yesterday.
TR: She used two triangles.
G3: I could use four triangles.

B2 has made a star by overlapping; I suggest he try it without overlapping. . . he says he will . . .
G3 has figured it (the parallelogram) out . . .



B3: Put it (refers to one of the triangles G3 is using) on the top (of the other triangles she's positioned).
TR: No it's great as she has it.
B3: She has to use all the pieces.
TR: She will.
B3: But she can put it on the top and get a huge triangle.
TR: Yes, but she's done that.



[Teacher's comments offered as perturbations not impositions and perceived as such. Teacher not seen as authority.]

Nov. 13, Wednesday

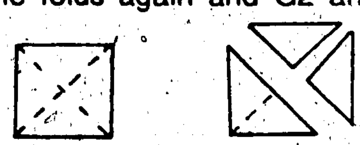
TR: I'm going to try to make a square out of the tangram pieces.
G3: To make shapes from my square, can I measure with these (referring to tangram pieces)

TR: Figure out how to get them from your square?
Girls: Yeah!
TR: Try.

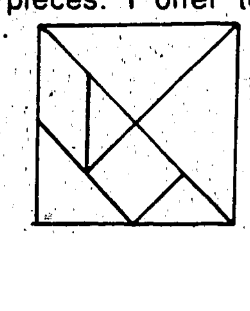
G3: How do you do this?
G1: Do it the way
G3: 'Cause like you have to get these shapes.
TR: If you want to get exactly these shapes you have to figure how he, did he get them from a square.
G3: (places a parallelogram on the paper square) First could I fold it right there and cut it, fold it right there and cut it.
TR: That's an easy way. You can do it that way if you want but it's not what I was hoping.
G3: Good 'cause this shape's hard.

I start folding my own paper square. . . ,

I fold a square into 4 triangles (two diagonals). I show G2, and help her recognize 2 big triangles at least.
G2: Try to get others from the other side.
G1 watched. She then asks about cutting around each shape . . .
TR:(to G1) Do you want your tangrams to be the same shape as these?
G3: I do too!
G2: Do like TR is; I am.
TR: Yeah, if you fold your square
G1: I want all the pieces.
TR: That's what I'd like to show you.
I show them the folds again and G2 and G1 fold theirs.



TR: G1, cut down the middle. Then cut it in half to get 2 triangles.
G1 and G2 are stuck. . . . I look and see G1 is trying to put the square together using the "plastic" tangram pieces. I offer to help . . . we put it together, mostly my moves.



TR: Now all you have to do is remember
G2: Leave this one and cut another one.

:

G3 holds up parallelogram she's cut . . . comes to get another piece . . . G1 isn't sure how to get the "second half" divided up.
TR: Fold the corner to the edge to get a triangle.
G1 tests to see if it's the same size as the triangle in the tangram set. She cuts it and I encourage her to figure out how the other pieces can be folded.

:

G3: This might not work. (She's cut two pieces and can see that the square is getting eaten away oddly.)
TR: Well, you can try it and if it doesn't there's lots more squares.
G2: This might not work 'cause I made it too big.
I shift her plastic square over a little so it's not over the edge of her paper. She's marking the pieces off.

:

G1 needs to put tangram square together again; she says she forgot how but proceeds to and I tell her it's right. She continues to cut based on the "figure". . . . G1 finishes hers. . . .

:

TR(to G3): Do you think it'll work out? Maybe you'll get some different shapes.
G3: I think I'll do what G2 did.

:

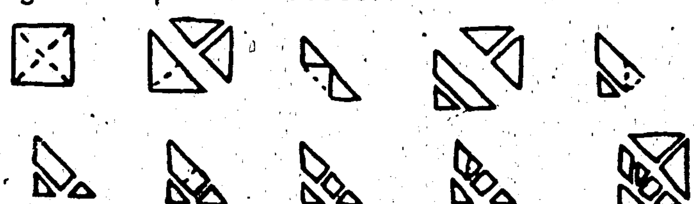
G3: How did you make yours?
G1: TR showed me.
TR: Can you show her?

:

G1 proceeds to show her . . . they call for help . . . I shift a square, otherwise they get it. G1 tells her to fold a paper square in half, . . . to get 2 triangles . . .

:

Now G3 asks how we did the bottom half. . . . Again I show how to get triangle by folding the point to centre edge. Then show her small triangle, which gives small square. She sees it; I suggest she cut that and get rest after. By the time I reach my chair she has folded it one more time and got the parallelogram shape she needed.



:

Nov. 18, Monday

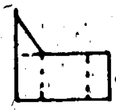
:

Looking at G3's folds. I mention triangles and trapezoids.
G1: How can I make a traffic-gon?

TR: Traffic-gon? A trapezoid you mean?
G1: That thing like this?

TR: Well, you got a square.

G3: Oh, I know how you make them.
G1: Cut the square in half; join it on the other side.
TR: Yeah, or what about if (I fold both squares in half) you fold this here . . . now can you see the square in the centre.



G1: Yeah
TR: Can you somehow make triangles out of each side?
G1: Yeah.

[Teacher/children/material system such that "directions" are given but the atmosphere is such that child chooses what to accept and where to go from there. It seems to be more of mutual sharing rather than authority telling the children what must be done. Social autopoiesis is present, since members have control of the group's generation.]

In the S3 setting, the interactions were not always "direct" in that comments were not necessarily aimed at a specific individual or individuals, and yet such commentary influenced the actions and ideas of others in the whole group. These communications, sometimes made by the teacher and sometimes by other children, were not commands or even suggestions, and yet they were used by others in the setting to generate activities and ideas.

Nov. 5, Tuesday

B3: This is fun.
TR: Do you like working these out.
B3: Yeah. It's too easy sometimes though.
TR: Maybe we can make some harder ones.
B3: Can you get harder ones?
TR: This is all I could find.

B2: I wonder how they figured this out?
TR: Yeah, I wonder, the ones who made it, what do you think?
B3: Which one?
B2: The guys who made this.
B3: Which one?

B2: This one.
B1: They're smart. . . . Creative Publications.

[This later led the researcher to suggest days later that we make our own tangrams and cards.]

:

. . B2 is not working on tangrams . . . chats about gobots. I ask him to pass me a card. He looks for me. G2 offers me one of hers. I take G2's card.
TR: I'll try this one.
B2: It's so easy. It is! I'll show you. See! (He takes the card and begins) That goes there. (I have another card in front of me but I watch him)

:

. . . B2 is working away. . . . B3 says he's finished his box and could he try the one I'd started. I hand it to him. . . .
(B2 jumps up) B2: It's simple. (to G2) Did you use all the pieces . . . in one bag or both bags? I used one bag for it. (He means the one he just completed)

:

Nov. 6, Wednesday

:

TR: I think I need 2 bags to do it! . . . Is that the sort of way you did it?

:

G1: No I don't think I did it that way.
TR: I had to use two bags. I think I'll try to do it with one!

:

TR: I can do it. I can do it with one bag!

:

B2 (leans over to me) : Oh, I didn't do it that way.

:

B1: Bet I can do this in one bag.

:

I pick up a card and say I saw B1 doing it. B3 said it was he who did it. Then I ask B1 if he did it one day too; he couldn't remember so he said he'd try it. He takes the card.

:

G3 and I work away at a card she is having difficulty with, but we are not successful. B3 pushes his way in.
B3: Can I try; can I try?
G1 leans over: Put two triangles in there.
TR: Yeah but we don't have two triangles.
We go at it briefly then B3 claims it and returns to his seat to try.
TR: Return it after 'cause I want to try it 'cause I know B4 did it yesterday.
G3: And B4 got it?
TR: B4 got it!

:

G1 passes G2 the card (she just finished).
G2: It's so easy with big triangles.

:

G1 watches G2.
G1: G2, you're not doing it the way I did.
G2: I don't want to do it your way.

:

I return to work at mine but I am unsuccessful.
TR: Did anyone get this to work?
B2, G1 and B1: Yes!
As I go to make a move, B2 reaches over saying; No, No, No!
Then he starts putting pieces in position as I watch. . . . B2 returns to his seat; I continue.

:

G3: I can't do it!
G1: G3, I did it.
TR: Don't give up on them. Oh I think I figured mine out. Thank-you B2. : . . See I couldn't figure it out, B2 helps me by moving a piece and then . . .

:

G1: (to G2) Can I borrow a triangle?
G2 refuses and tells me what G1 had requested.
TR: I'm often missing one too but when I rearrange it, it works out.
B2 offers a triangle, G2 too.
G1 refuses 'cause she does want to do it.

:

G1: I wasn't missing one. TR, I wasn't missing one; I just had to do it a different way.
TR: Look at it, yeah! That's what I'm trying to do now.

:

B1 decides to try the one B4 had done . . .Recess . . .B1 keeps at it.

:

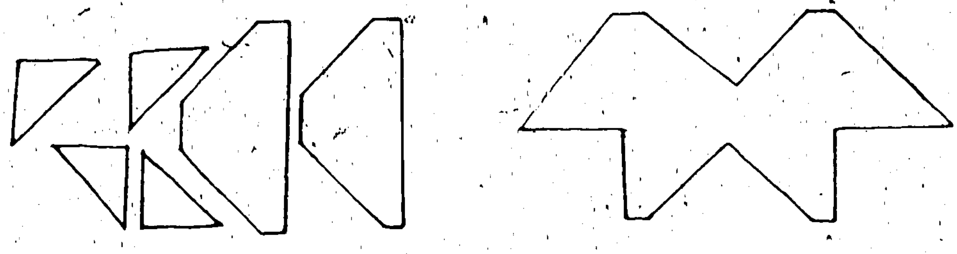
[Undirected perturbations and precursors i.e "using one bag", "picking a particular tangram card", hang in the atmosphere and are chosen as "kicks" for unpredictable pursuits by members of the system.]

One further development which occurred as a result of activities in this setting was the expansion of social autopoiesis to include children who were not members of the enrichment group per se. Towards the latter part of the study, other children from the regular classroom gathered at our area during recess, and often spontaneously became involved in the experience.

Nov. 21, Thursday
Recess . . .
B3 (to B4): You're not allowed to do them today.

:

B4 (looking at G3's shapes): Wierd, it looks easy. Can I try it?



G3: Try it!
TR: You shouldn't let him do it yet.
(B5 enters; asks B4 if he can do it)
B5: That goes there.
B4: No it doesn't.
G3 watches. B4 continues, B5 by his side. . .

B4: Hey wait! Ah, ah!
G3: I think you found it.
B4: No kidding.
G3: I think you did find it.
B5: Yeah that's it!
B4: No 'cause it don't fit exact.
B5: Go like that. I know it. No not like that B4!
B4: It doesn't fit.
B5: Does so.
B4: How?
B5 takes it and is about to place it . . .
B4: Oh should have.
B5 puts it in place. B1 pulls B5 away. B4 puts the next piece in position . . .
B4: Here we go.
B5 returns immediately. . . . B4 proceeds to do next side. . . B4 completes it, moves over to G1 . . .
B4: This one is harder.
G1: That's not the way to do it.
B4: How do you know?
G1: Well, you could but it's not . . .
B4: I'm good at these things.
G1: It's not the way I did it.
B5 and G3 watch . . .
G3: It's way different than how G1 did it.
B5: Do it like this.
B4: I know.
B5: Do it like this. Brother, it's easy.
G1: That's not what I did either.
B4: I know.
B5: But it's easy.
B4: So I like it this way.

B5: It won't fit . . . B4!
B4: Move I'm trying to do it.
B5: Here try this.
B4: NO!

B4: This goes here.
B5: Oh, he did it a different way.
G1: He did? . . . Here I'll show you how I did it. (She redoes it.)
B4: I did it a different way.

B4, G3 and B5 watch G1.
B4: No wonder, I had it in the same way but wrong place. Yeah I made it different. Thought so. Told you, I'm good at these, . . .

[Boundaries are expanded to include "non-members" in an autopoietic social system. Children/material system is self-generative. Also, members mutually amplify one another's ideas. Individuals are also able to maintain their own organization by compensating for the perturbations introduced by others.]

From such examples, it is evident that the coupling of autopoietic units such as children (and researcher, in a setting such as S3, involves a vast number of potential social configurations. Children interacted in groups of different numbers, whose members sometimes varied from moment to moment. The participants often did not request the comments of others, but they were volunteered anyway. The general atmosphere was such that even "off-handed" musings of particular individuals served as precursors for further action or dialogue. The members possessed control of the generation of both the ideas and the relations which were exhibited. Hence, social autopoiesis was amplified in such an environment.

Summary

Social autopoiesis is not a static phenomena which is either present or absent. Rather systems may at times be autopoietic while under differing circumstances be more allopoietic. When autopoietic units come together often spontaneously in dialogue, the resulting system may amplify autopoiesis or may amplify allopoiesis. Children, who we see as autopoietic in terms of creative potential can and do readily submerge their autopoiesis and opt for an allopoietic role under particular circumstances. At other times the autopoiesis of the children in turn enhances the autopoiesis of the group. However, reciprocity, within far from equilibrium conditions where there exists a free exchange of ideas, tends to permit the release of autopoiesis more readily than hierarchial settings wherein dialogue is limited to the transmission of information.

Reflections on the "Mathematical Niche"

Reflecting on the previous descriptions of autopoiesis, in the S3 setting in particular, a tension between the child's mathematical niche (i.e. child/material systems) and the "social systems" niche (i.e. teacher/children relations far from equilibrium) seems to be present. That is, as mathematics educators view S3, it might seem as if attempts to drive the "social" system far from equilibrium, the "mathematical" niche is destroyed or lost. As indicated in Chapter III, to encourage the freedom and spontaneity of the learners and thereby maintain the far from equilibrium context, the "straight line", "perpendicular", "diagonal" folding, common in DMG, was all but abandoned and children pursued "paper cutting" in their own individual ways. Even though, this "relaxation" of a "prescribed paper folding and transformation activity" resulted mainly from the autopoiesis of the children involved, educators might feel that the curriculum experiences in S3 expanded the boundaries of the mathematical niche to such a point that "valid" mathematical insights could no longer be derived. Indeed, observers may perceive activities such as the "Hallowe'en project" as those in which the mathematics is lost and children digress into "frivolity".

In considering this issue, there are several views to explore. On the one hand, there is an urge to delineate the numerous mathematical properties embodied in such activities. For instance, as children built their Hallowe'en figures, transformations (flips, turns, slides) were used exhaustively to position the pieces into just the right pattern. Likewise, these same transformations arose as children positioned their figure on the "Mural". Inside/outside boundary issues arose when children, while cutting one shape from a rectangle, discovered a second shape in the remaining piece. "Traditional" shapes of triangles, squares, parallellograms and so on were at times utilized and therefore acted as perturbations. There was even potential for building of structures as the "zombies" reflected shapes and curvatures of the "many sided figures" some children had pursued earlier; or the "cat and pumpkin" evolved from the same eight triangular pieces. The list could continue no doubt, however, it is sufficiently clear that even Hallowe'en figures embody mathematical concepts and properties.

On another level, it is possible to disregard the presence or absence of "mathematical properties" per se, and still see such activities as resonant with Dienes' and Piaget's "exploratory" or "play" stage of mathematical development. As Dienes (1960) pointed out

> Piaget was the first to see that the process of forming a concept takes longer than had been believed and that much work, seemingly unrelated to the concept must be done before there is any clue to the direction which the thinking is taking (p.23).

Therefore, experiences such as the Hallowe'en Mural could be seen as exploratory ones in which children toyed with creations and ideas that might serve as the groundwork for future mathematical ideas. This playing around with ideas is further supported by Whitney (1985).

> We know that very young children explore their environment and learn in manifold ways at a rate that will never be equalled in later life; and this with no formal teaching. It is through their play that they experiment, see interrelationships, get some control over surroundings . . .
>
> The broadness of their learning is certainly largely due to their complete freedom to think in any direction at any moment; curiosity, imagination and flexibility are keys to their rapid progress. . . . (p. 222)

Since children could pursue the paths they desired, their "sense making" was probably enhanced rather than depleted. With control over "closure" of the task and the directions in which they could experiment, children had the opportunity to encounter mathematical ideas which in recursive ways may lead to more formal reflection in later experiences.

As well, such arguments are further enhanced by the "wholeness ontology" underlying the systems paradigm. The debate necessarily transcends particular properties of materials or even processes with which the children are engaged. The crux of the issue depends largely on our world view. Within the "wholeness ontology" (in sensu Sawada and Olson, 1986), mathematics, like any other aspect of living, is pervasive and cannot, no matter how hard we try to cut up the world, be detached from any of our experiences whether they be in or out of school, formal or informal, conscious or unconscious. Through the interconnectedness of all that we are and all that we do, mathematics cannot be an exception and be seen as separate from other activities. As Darcy and Jayaratna (1985) explain, "partitioning of any world view into two components of: the 'system of interest' and the 'attendant environment' necessarily requires the <u>imposition</u> of some <u>arbitrary</u> separation" (p.85) (my emphasis). That is, partitioning 'mathematics' as discrete from the 'learner and the learner's environment' is both superficial and arbitrary; the result being then an attempt to reconnect the "cut" by suggesting salient features among the two.

In a Newtonian paradigm where children are led to perceive mathematics as "addition and subtraction", those artificial boundaries often become barriers to understanding mathematics. For those who see mathematics as a discrete subject separate from science, separate from art, separate from life in general, the perceived tension between the mathematical niche and the far from equilibrium system is problematic. For those who recognize the pervasiveness of mathematics, there is no dichotomy between Hallowe'en figures and mathematics; there is no threat of losing sight of the mathematics because its presence is implicit. Thus, through the very autopoietic coupling of learner/material in the far from equilibrium setting, the "mathness" of the experiences is further enhanced.

CHAPTER VI

Conclusions

The findings presented in the previous chapter are summarized in the form of conclusions which have been organized under three broad headings of context, content and living systems. These conclusions are then embedded in reflections on the living systems metaphor. The dissertation is then closed with some suggestions for further research.

Conclusions with Respect to Context

1. When parameters are set externally to the system (i.e. preset curriculum and text) and implemented by an authority figure, such as in S1 and S2, systems remain at or near equilibrium; when parameters are set internally through the interactions of the members, as in S3, systems move far from equilibrium.

2. In contrast to the rigid, predetermined boundaries of AE and NE systems, the boundaries in a FFE system are more permeable, and spontaneously created.

3. Mutual causal processes are an apparent feature of interactions FFE while NE and AE more hierarchial and unidirectional processes are engaged.

4. Perturbations, which arise mainly from an authority, as in S1 and S2, are perceived as dictates, while perturbations which arise from "equal" members of a system are perceived as deformations to which individuals respond in personal ways.

5. Heterogeneity is a common characteristic of the FFE setting whereas homogeneity dominates the AE and NE settings.

6. In S1 and S2, spontaneity is limited and deviations are pulled back to equilibrium, while in S3, dissipative structures emerge .

Conclusions with Respect to Content

1. Mathematical content, such as DMG used in S3, perturbs the learner and encourages creativity whereas mathematical content, such as the textbook exercises used in S1 and S2, encourages 'rote' response.

2. Algorithmic exercises, as used in S1 and S2, discourage equifinality and emphasize the "one" right way; activities, such as DMG, embody equifinality and encourage learners to seek the many paths to a solution.

3. The openness of mathematics like DMG used in S3, allows the learner to produce ideas which in turn affect the material which in turn affect the ideas; whereas mathematical algorithms, as used in S1 and S2, are "closed" in that the learner contributes little to the product other than carrying out the technique.

Conclusions with Respect to Living Systems

1. The actualization of a living systems metaphor in mathematics education is possible.

2. The FFE setting is more conducive for the release of autopoiesis.

3. There is an interplay between social and individual autopoiesis when autopoietic systems couple to form a social unity.

4. Heterogeneity is vital to the maintenance of autopoiesis.

5. Autopoietic systems play allopoietic roles in "externally structured" social settings, such as S1 and S2.

6. A particular setting is not necessarily autopoietic for all individuals involved.

7. In living social systems, such as S3, learners compensate for perturbations in an attempt to maintain their own identities and organization; they adapt or transform the experience to fulfil their needs.

8. The actualization of a living systems metaphor in educational

research is possible.

9. An autopoietic researcher/research system is central to such an educational research paradigm.

Overall, then, this study revealed that the "living systems" metaphor is a "viable" one for mathematics education in that it provided an enriching alternative to the regular classroom setting and showed potential for altering our traditional approach to mathematics education in general.

Reflections

To discuss these conclusions further, and to embed them in the context from which they arose, we need to reflect on the actualization of the "living system" metaphor and its contrast with the metaphor present in the other settings.

Enrichment Small Group (S3)

Over the short time span of the study, I (the researcher) and a small group of children created a "living" mathematical experience for ourselves. Seven of us interacting with each other, using DMG as our mathematical focus, generated a coherent unity, both social and individual, that for us was very distinct. At no time was there homogeneous group activity, but rather the heterogeneity experiencecd was in itself a vital component of the "living system". The fact that each of us could be "true" to ourselves while in turn being "true" to the group was an essential ingredient permitting the group's growth. As individuals we each had opportunities to choose the interactive moments as well as the "autonomous" moments as we desired. Under such conditions, we moved freely in and out of conversational groups sometimes as leaders, sometimes as followers and at other times as observers. Most times we were enthusiastic, or in systems terms far from equilibrium, and even the simplest suggestion or comment had more impact than we might suppose.

We generated a group coherence wherein, even though to observers our actions seemed rather independent, we were constantly aware of each other and the overall focus of the "system". Subtleties abounded, and even undirected "kicks", lingering in the atmosphere, triggered an idea or a development in another member of the group.

With respect to the specific dynamics, the boys appeared to be much more independent than the girls. Throughout the study the girls overtly conversed and openly aided each other on tasks. The boys, on the other hand, did not often request ideas or help from one another but were indeed influenced by each others comments or activities. One boy in particular appeared to be totally autonomous in that often his only "connection" with others was personified by conversations concerning T.V. and movies. Indeed I frequently noted in my diary that B3 was "along for the ride" and wished membership only as an escape from regular classes. Data analysis however revealed that this was the surface picture only; indeed his membership in the group was much more substantial. He too was carrying out the activities in his own way as were the other children and he was also infuenced by "kicks" in the environment. This was overtly obvious during the tangram episodes in which he took a keen interest, but was present at other times as well.

The unity of the group was a special feeling of interdependence and togetherness which developed as we worked. Its place in the children's perceptions was visible in a variety of ways. Their attempts at various times to deal with B2, wherein they encouraged him to join the activities, to participate more fully, seem to indicate their perception of some global "scheme" which they valued and which they believed was threatened by his behavior. Their reactions to outsiders was another indicator. They shared their experiences with peers outside the "group" but also took pride in the "exclusive membership" they held. When I chose a second group toward the end of the study, my original group needed reassurance that they would continue and were curious as to what the others did with particular concern that the second group not do what they were doing. This implied that they did not see themselves as six separate children doing the mathematical tasks but rather the "group" was seen as an entity. When the "wholeness" of the group was threatened, they feared the loss of the "experience" they shared.

Of course, the group was not a static unity and within the global group of seven, smaller groups were formed and dispersed at will. At times new subgroups formed and lasted for long periods of time; while other times the interactions holding a new subgroup quickly dissipated. The changes in boundaries were self generated and at times involved the incorporation of others to attain "physical help" while at other times the coming together was "idea" centered and resulted because of common interests. The conversations were nonlinear and often recursive. They at times extended beyond sessions, even over several days; at times they were interrupted by other conversations and renewed again later. Some conversations even drew "outsiders" into the event whereby other peers who did not belong to the "group" per se were included in the dialogues. Such loosening of the "larger" system's boundaries was evident toward the latter stages of growth. At this time children chose to carry work home to complete and to share with parents; they told other children as well as other teachers of their activities and their plans; they invited "curious" peers to try out some of their activities. In this sense then the boundaries were flexible and indeed constructed by the members.

The cohesiveness of the "system" was felt to be strongest for me when I participated fully in the tasks at hand and thereby became a "complete" member. When I worked autonomously with the materials, my membership within the group dynamics proved to be much more "honest". When I played the role of "overseer", although a "physical" member of the "system", I was seldom privy to the legitimate interactions and relations which held the group as one. Instead, I was viewed as an "authority" and conversations with the others usually involved question and answer sessions, or requests for help and the giving of directions. On the other hand, as an "active" participant similar to the children, interactions between the children and myself were much more "natural" and "reciprocal". Now, they offered help to me as they would to other peers; they gave encouragement and made suggestions. Even requests made on these occasions seem to be similar to those they made of each other. My conversations also altered in that suggestions were initiated on a more "equal" standing as well; rather than "teacher" telling "child" what to do, a "colleague" offered ideas to other "colleagues".

The mathematics material as a precursor for interactions was a vital component of the "system" as well. The openness of DMG became more and more apparent as the variety of children's responses to such tasks became evident. Allowance for personal creativity overrode the researchers initial urges to impose a rigid DMG curriculum. The boys in general did little folding but instead preferred "cut and paste" methods of making new shapes. However, in this setting, the boys still picked up numerous ideas concerning DMG. They pursued the naming of figures; they recognized the effects of transformation of pieces. The girls' activities on the other hand involved much more folding and their products were more "regular" then the boys' shapes. One of the boys spent much of the time making "animal" shapes; while one girl produced mostly parallelograms and trapezoids and so on. The paths followed by each of us were rather diverse and particular goals like "journeys" or "making tangram puzzles" were interpreted differently by members, thereby adding to the heterogeneity.

Such freedoms to "experiment" with our own ideas led to the self-generating character of the "living system". Both children and researcher held control not only over their own individual tasks and goals but also with respect to contributing to the direction of the group as a whole. Expectations and parameters were set privately at times but often evolved from mutual interactions among members. Ideas generated operated as perturbations to which each of us responded in our own ways in order to maintain our own identities. We also generated the relations through which we participated with each other, and from these relations, we, in turn, generated more ideas which led to other relations and other ideas. Reciprocity was a key ingredient within such relations and little unidirectional, 'do as I say', commands were made and even fewer were accepted.

It was also apparent that the "system" between the learners and the "mathematical" tasks themselves were highly recursive. Learners did not manipulate the materials rotely nor blindly; but rather comments by other children as well as reflections on personal "moves" led to inferencing and the making of connections. Children's comments often indicated they linked previous tasks with the task at hand and would incorporate ideas garnered at one point within a task at another point later in the task or revise ideas and use them to complete a different task or alter the task. Many of the ideas and connections were not formalized per se but given more time this may have indeed happened.

Therefore, it was undeniable that these learners, the researcher included, were autopoietic systems far from equilibrium. When such autopoietic units coupled through mutual interaction, the new unity also possessed the essential elements of a "living system". Indeed, children's comments in the interview revealed their knowledge of the significance of the openness and interactive milieu which encompassed the group. One child in particular speculated that indeed such should be the experience in all school courses.

Regular Classroom and Regular Small Group (S1 and S2)

These same "autopoietic" systems, i.e. the children and the researcher, suppressed such characteristics within other settings. In the regular classroom the girls in particular were subdued and obediently followed instructions given by the teachers. Indeed early in the study, this desire to do the "right" thing was visible in both the regular small group and the enrichment small group. The boys also for the most part followed the teachers directions but did so usually under protest in many S1 sessions. In the S2 setting, they continued to fulfil external criteria although some minor personal alterations were made. In S3, the boys asserted their independence early and did not seem as willing to do a task for the sake of the "authority". Since the interactions between learners in S1 and S2 were limited, children seldom initiated ideas for each other and when they did, it was often perceived as a "problem", (i.e. cheating or lack of discipline). When these settings provided the opportunity for dialogue, it was grasped willingly and enthusiastically, as evident when they worked in small groups with peers or were given the freedom to discuss. On the occasions when the material being studied encouraged a creative approach, many children arose to the challenge. Hence, it would seem the children were autopoietic systems who were adopting allopoietic roles, when the setting required it.

It was also evident from experiences in these settings, that one cannot really term an episode as autopoietic or allopoietic per se. Rather, a particular episode may have different effects on different members. Therefore, an event may encourage the release of one child's autopoiesis while curbing another's. In the same instance, social autopoiesis may emerge for some members of a whole and not for others. Thus, rather than labelling a setting as either allopoietic or autopoietic, we need to recognize that a setting possesses potential for both.

In contrast to the FFE setting (S3), these other two settings were based on an unidirectional, hierarchial paradigm. When transmission of information was the emphasized mode of communication, little creativity emerged. Rather than participants building on one another's ideas, a central authority dictated the procedures to be followed and the information was collected but not reciprocated. When conversations were generative in settings S1 and S2, as with open discussions or creative writing, reciprocity was present and there was no telling where initial comments or ideas might lead. Digressions were common and conversations were nonlinear, and often spontaneous. During such episodes observations revealed that even when the teacher percieved comments to be chaotic and off topic, the discussions were self-generative and if permitted to evolve might indeed lead to the same goal as intended by the authority or maybe even to an unanticipated goal. In setting S3, such unanticipated paths were given the opportunity to emerge or dissipate according to the reciprocal interactions of the participants and often they did lead to a desirable end.

In settings S1 and S2 although perturbations were present, children were for the most part unable to respond such that they might maintain their identity. Instead, response to mathematical perturbations were usually in the form of an algorithm which all children in the class employed in a similar manner. When confronted with a "problem", children usually followed known preset procedures or requested direction from the teacher.

Summary

It was revealed through this study that autopoietic social systems can be "created" in school settings. In a far from equilibrium setting wherein precursors include the children, the teacher, and the materials such a system was actualized. The reciprocity among components entailed a major aspect of the interactions and relations needed to release both individual and social autopoiesis. The organization of the "living system", the relations between components, took precedence over the characters of the children, the properties of the components. It was the interactive, heterogeneous environment which was the prevalent factor, not the particular children or teacher present.

Suggestions for Further Research

At this point, I must reflect on the research experience as a whole, remembering how during the research experience it was difficult to separate the research per se from that being researched. Like Escher's sketch of "hands drawing hands", in this study, the use of a "living system" to study a "living system" created an interdependent and nested research suprasystem wherein every level was intertwined with the other. From the initial chaos of the "open" research process there emerged an "ordered" research design. Rather than adopting a preset design or research methodology, this researcher entered the arena with the intent to collaborate with other participants in the study in a reciprocal fashion so that together they might generate the research focus as well as the means for carrying the research to fruition. At all times during the experience, the research paradigm like the "enrichment subsystem" under scrutiny, remained conceptually resonant with the "living systems" metaphor. As a consequence, the researcher/research system, like its counterpart, the learner/material system, was autopoietic. Both the research process and that being researched evolved and changed together, each affecting the other as in any mutual causal relationship. Research decisions were informed by general system theory but just as "precursors lingering in the atmosphere of the enrichment group triggered unpredictable pursuits for the learners", likewise "precursors lingering in the atmosphere of the collaborative research experience triggered unpredictable research pursuits"; this was true during the field experience as well as the data analysis and the writing of the report.

To remain consistent with the "living systems" metaphor, suggestions for further research are to serve as precursors only for myself and others in the research community. The initial "kicks" offered are done so in the spirit that they lead many of us in numerous directions pursuing a similar goal. As a proponent of a "living systems research" paradigm, I suggest we maximize opportunities in our research where the autopoiesis of all members- the teacher, the child, the researcher - be enhanced. As a heterogeneous research community, we need to further explore and expand the potential of this "new paradigm" prevalent in other disciplines for theory and underlying assumptions which can and should guide us as educators and researchers. Likewise, we need to explicate and actualize models of education and educational research wherein teacher/child/material systems and researcher/research systems respectively are autopoietic and "living". Through continued exploration of the "living systems" metaphor, for which this study serves as a precursor, educational researchers have an opportunity to generate an alternative research paradigm which may, as Caley and Sawada (1986) indicate,

. . . through its rich diversity, recursively engender nonlinear forces that propel the system to new levels of greater complexity -- new higher order knowledge (p. 10).

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