

Simulosophy Group Report

*Asilomar Conversation, Nov. 13 - 18, 1994
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Design of Social Systems*

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Musical Overview

Kayla nicely summarized the week's conversation in the form of a song, to the tune of *My Bonnie Lies Over the Ocean*.

BRING FORTH SIMULOSOPHY

Before we were each tiny islands
Thinking simthoughts privately
But this week we have harnessed our passion
On a thing called sim-u-los-ophy.

To simulate it you must know it,
So we spent a good deal of our days
Sim-ing the whole darn ed. system,
And believe us, that was quite a maze.

*Chorus: Briiing forth, briiing forth,
Bring forth SIMU-LOSSS-OPHY, SO-PHY,
Briiing forth, briiing forth,
Bring forth SIMU-LOSSS-OPHY.*

We looked at the SIGG's systems model
We examined a whole set of rules,
We imagined a CAD SimEd software,
Full of system designer tools.

But we need a new language with symbols
To see human systems on screen
We're entrenched in industrial models
That won't help us with all that's unseen.

(Chorus)

Then we freed our tired brains for a brainstorm
And we made some sketches and schemes
Closer and closer we're getting
To simulate our systems dreams.

So we hope you are now simulated
From singing that simulant song
Thanks for your care and attention
And now we will simu-a-long.

(Chorus)

You won't find 'simulosophy' in the dictionary. Kayla must be given credit for coining the term late Monday afternoon after a productive day of simulosophizing. Simulosophy might be defined as the "design of worthwhile simulations." Our goal is to design the simulation of an educational system that will change the way people think about education. We hope that it will help them to think systemically.

During the 1994 Asilomar Conversation our group worked to build the foundations for an eventual multimedia simulation of educational systems. Our vision is that this simulation (call it SimEd for now) would be similar to SimCity, SimHealth, SimAnt, etc., in that the eventual user would be able to construct different kinds of educational systems and observe how they evolve through time. By observing the consequences of certain decisions and actions within SimEd, users can learn from mistakes □ without suffering the consequences had such changes actually been made in a real educational system. We envision such a tool to help educators, students, parents, school boards and administrators, and communities at large to make intelligent decisions about how to improve or change their own educational systems.

Some Results from this Conversation

Key Ideas from Monday's Conversation:

- . The simulation should allow users to play out alternative futures (e.g., to see what happens to the current system if no major changes occur; parents can see what happens if schools don't change in the next 20 to 30 years; users can play out "what if's").
- . The simulation should flag incompatibilities in a systems scenario.

We should examine both conscious and unconscious assumptions that we have about education, which should then help us to identify elements to consider in a simulation.

A simulation should allow players to:

- design systems like a tinker-toy or erector set: there are many components; there are existing models to create; there are instructions for doing so.
- teach/embed systems intuition.
- shift from industrial information age models/tools.
- develop life-long learning systems (we need to continue our education through our lives).

Players should be able to indicate their values and beliefs up-front, which should then act as constraints and guide decisions and choices.

We need to have descriptions of cases (like casebooks that lawyers and architects can refer to). This will allow players to learn from the experience of other's attempts to design educational systems. This could be something like the almanac that is part of "Where in the World is Carmen Sandiego?" This information could become available through the simulation process as one gets more sophisticated in finding and using information.

The simulation could be one of many system "design aids" to break mold, to get comfortable with other models, and to develop hybrid systems.

Generic Principles for this Educational System Simulation/Game:

1. Be able to start with the existing educational system (i.e., the simulation should be able to model it) and watch it grow/destroy.
2. Be able to build a new educational system from the ground up.
3. Be able to test a new educational systems model for efficacy.
4. Given an existing paradigm (e.g., Montessori's system of education), be able to do variations on it.
5. Start with an existing system (as in #1 above), but try to make it better.
6. Given an existing "terrain" (context), be able to design a system within those constraints.
7. Be able to go back in time (in the simulation), and change some decisions or parameters, and then watch it evolve ("back to the future" notion).
8. Be able to do worst-case scenarios to see if the educational system that is designed in the simulation will be able to survive. In other words, be able to test the robustness of the design in its ability to withstand "disasters."
9. In the simulation, there needs to be a capacity to invent, design and refine "assemblies" (i.e., components, subsystems, subroutines).
10. The user should be able to appreciate good vs. bad designs in the simulation.
11. The simulation should have the capacity to:
 - 11.1. Enable stakeholders to understand, evaluate, and to critique designs and design alternatives.
 - 11.2. Play out longer-term consequences to observe: unanticipated side effects, "shocks," component failures, degradation of context, environment, resources, etc.
12. Games, simulations, etc. should enable key players to learn, refine, and master their roles and positions (duties/functions) and likewise for interactions with others.
13. Games and simulations should allow compression or expansion of time, and that allow a user to zoom in or out on system(s) detail (micro vs. macro views).

14. The simulation should allow users to "invert" design assumptions and to substitute contrasting paradigms, different rules, etc.

Potential Rules for the Educational Simulation (from Wednesday's brainstorm)

1. User can only control the system or negasystem, but not both; or user can play "god" and control everything.
2. If there are multiple players, each can control their piece of the action.
3. Start with a given amount of money and other limited resources (e.g., political friend, parent group, teacher organization, superintendent, school board -- some of whom are allies and others who are obstacles or enemies)
4. You "stagnate" when (*maintaining* system):
 - 4.1. You maintain the status quo (community does not grow in size, no new business, no new houses, etc.).
 - 4.2. Efforts to change educational system fall on deaf ears.
 - 4.3. Curriculum content does not change as societal needs change.
 - 4.4. You optimize a sub-system, which means you have created a sub-optimal system.
5. You "win" when (*constructing* system -- i.e., a learning organization):
 - 5.1. Graduating students get jobs.
 - 5.2. Graduating students create new jobs, businesses and community services.
 - 5.3. Graduating students go on to higher education.
 - 5.4. Good teachers stay on and get rewarded for promoting student attainments; poor teachers quit or are fired.
 - 5.5. The local community survives/evolves/grows.
 - 5.6. People respect each other, care for each other, and look out for each other's well-being.
 - 5.7. People respect and care for the ecology and surroundings.
 - 5.8. People vote intelligently in elections for good representatives in government.
 - 5.9. The local community is diversified in terms of sources of income (they don't become vulnerable by depending on one big company).
6. You "lose" if (*destructing* system):
 - 6.1. Your community goes "belly up" (folks leave, business moves away, tax base erodes, infrastructure collapses).
 - 6.2. Good teachers leave.
 - 6.3. Most graduating students leave your community as soon as possible.
 - 6.4. Graduating students or dropouts join gangs that contribute to crime and destruction of life and property.
 - 6.5. In your community there is a general lack of respect and care for other human beings, which is indicated by increased violence, drugs, murder, arson, theft, etc.

Potential Conditions that Might Occur in the Educational Simulation (from Wednesday's brainstorm)

1. Random events: political events, business manager embezzles money from school, heavy weather (schools close), earthquake, district is awarded a large grant (opportunity knocks), school board majority now favors innovation, trusts school/community to solve problems, wealthy patron endows school with large sum of money for (random variable: school improvement, capital investment, etc.)

2. "The givens" which are non-modifiable: location, starting date, geography (except fire, flood, quake), size (state, district and local boundaries), start as urban, rural, or suburban community, public or private school, wealthy or poor school, student profile level, parent profile level, teacher profile level, community profile level, starting budget.

Potential Tools for Use in the Educational Simulation (from Wednesday's brainstorm)

1. Select students for educational system
2. Select teachers for educational system
3. Select content/curriculum for educational system
4. Select contexts for educational system
5. Professional development options
6. Tools are constrained by role and by finances/budget
7. Health/social services options
8. Learning resources options
9. Learning environment options
10. School layout options
11. Parent involvement options (many levels)
12. Open vs. closed campus
13. Personalized vs. group-based instruction
14. Teachers' role options (lecture, coach, sage on the stage, guide on the side)
15. Variety of instructional strategies and approaches (different strokes for different folks)
16. Building/site/equipment; maintenance; cafeteria options
17. School-to-work options;
18. Policy options (national, state, local)
19. Tools to get information; tools to make changes
20. Learning technologies (from story-telling to computer use)

Potential Consequences that Might Occur in the Educational Simulation (from Wednesday's brainstorm)

1. Riots, civil war, complete social disorder and chaos
2. Increase/decrease in welfare recipients, unwanted pregnancies, disease and epidemics, foster children, malnourished young children
3. Loss of community viability; students and families move away
4. Teenage computer hackers
5. Parent satisfaction
6. Local business satisfaction
7. Child care needs met?
8. Demand for schooling (rate)
9. Teacher satisfaction
10. Teacher learning
11. Taxpayer satisfaction
12. Physical condition of site
13. Transportation performance
14. Cafeteria performance

15. Student Outcomes: level of student achievement; efficiency (rate) of learning; affect/motivation/appeal; what is learned -- is it valuable? (facts, understandings, skills, higher-order skills), attitudes/values (honesty), qualities (initiative, responsibility, nutrition); kinds of knowing: qualitative, quantitative, praxic, and inventive; success of graduates (job placement); health consequences (pregnancy, drug use, sickness rate, exercise/fitness); mental health and emotional development; moral development; civic orientation; delinquency and dropout rates; tardiness and absenteeism rates.

Potential Leverage Points in the Educational Simulation (from Thursday's brainstorm)

0. Abandon compulsory education
1. Fromputs: assessment of student attainments
2. Toputs: abolish *state* controls (policies, textbook adoption, etc.)
3. Feedin: teacher selection for educational system (get rid of licensing; focus on student attainments)
4. Decentralize control of decisions (budget, policy making, instructional strategies, curriculum resource selection)
5. Allocate resources (\$\$\$) directly to classroom/student level. Get rid of bureaucratic culling that strips away over 60 percent of funds before they ever get to the classroom level.
6. Create the WILL TO CHANGE (in all the stakeholders).
7. Get buy-in from the top in chain of command.
8. Create a critical mass (coalition formation) that enables power (from below -- especially for example the teachers' union).
9. Allocate resources according to needs assessment. This should be done by those closest and who are directly connected to the students.
10. Take time up-front to develop sound vision, design, etc. and maintain flexibility to adapt but not lose focus.
11. Remove sanctions for change/innovation.
12. Build communications links between key components in the educational system.
13. Open the flow of accurate, timely information -- no filtering, no censoring, no spinning.
14. Be clear up-front which stakeholders are part of decision making and how they will participate.
15. Base policy decisions on learning research (get timely access to this information).
16. Understand "time lags" and how that will affect your system as you make changes and add innovations (i.e., results are not immediate).
17. Do serious professional development: sabbaticals for teachers and teacher development time.
18. Provide time to reflect (regular retreats and *conversations*).

Potential Trade-offs in the Educational Simulation (from Thursday's brainstorm)

1. Put all your money into hardware, but then no money to train users (and vice-versa).
2. Higher visibility means greater accountability to the public (they'll be watching you) vs. staying low-profile and having greater autonomy.
3. Structured schedule vs. flexible schedule (for student learning activities)
4. Large group instruction vs. personalized instruction
5. Print technology vs. virtual reality technology
6. Life-long learning vs. K-12 learning
7. Investing time and resources in change vs. status quo maintenance
8. Short term gains (you win now) vs. long-term sustainability (you lose later)
9. Virtual information access vs. local access
10. Design assessment for system improvement vs. accept assessment as a public relations tool
11. Diversity of kinds of schools and objectives vs. efficiency of operation
12. Competency-based model of student attainments vs. time-based allocation (e.g., 13 years for K-12).
13. Local autonomy over goals of educational system vs. national standards for goals.
14. Efficiency vs. effectiveness. While achieving both is potentially feasible, they usually end up being trade-offs, particularly when effectiveness means accomplishment of *diverse* kinds of student attainments. For example, it might be most effective if every student had a personal tutor, but it would be more efficient to group them in large classes for group-based instruction.
15. Centralization vs. decentralization. Centralization may decrease overall costs, but you give up local control and increase the likelihood of consumer dissatisfaction because the key decision-makers are removed from the day-to-day activities in the classrooms.
16. Do research on educational systems design vs. act now.
17. Plan vs. act.
18. If you invest highly in one innovation, then you won't have money, time and resources to do another well.
19. Equality of educational opportunity vs. diversity of educational programs and goals.
20. If you go private (less student diversity) vs. being open to all (more diverse population)
21. Isolation (to get more work done) vs. coordination which takes more time and energy and may get less work done.

Input Paper by Ted Frick, which influenced Tuesday's Conversation

The SIGGS theory model helped to focus the group's thinking on Wednesday and Thursday. Ted shared the big ideas from this model on Tuesday morning and afternoon. Details are in the paper which follows.

SIGGS Educational Theory¹

Concepts: Definitions and Comments

Theodore W. Frick

Draft -- not complete

Universe of Discourse, U

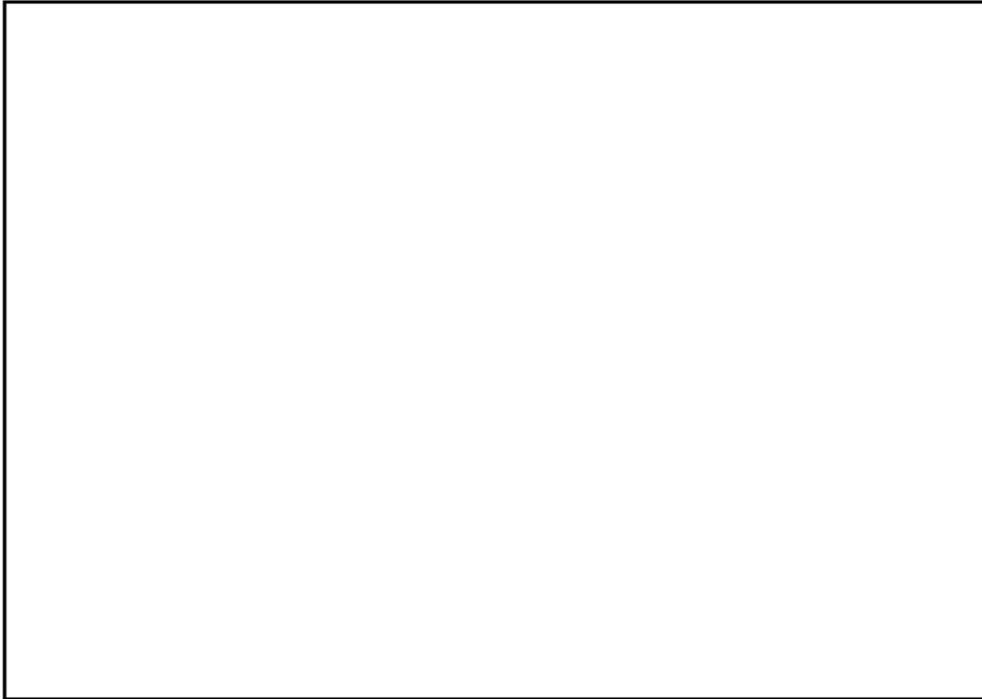


Figure 1: Set theoretic depiction of the Universe of Discourse

¹Maccia and Maccia's SIGGS Theory Model is more broadly applicable than described here. This description narrows the model and theory to *educational systems*, not systems in general, nor school systems. Their theory pertained to school systems, which are only one way that education can be arranged, conducted and organized. Quotations with page numbers are taken from Maccia and Maccia (1966). I have also taken the liberty to remove most of the "-ness" suffixes to improve readability, and occasionally emphasize parts of definitions with italics.

1. Universe of discourse, U

1.1. This is a primitive term. Primitive terms are undefined. Otherwise, circularity would be introduced into a definitional system. The universe of discourse is whatever the inquirer deems it to be -- i.e., all that is relevant to the problem at hand. With regard to education, the universe of discourse would include educational systems and their surroundings, communities, states and nations, depending on where one wants to draw the line.

2. Component, s

2.1. This too is a primitive term. Components of the universe of discourse in education could include people, living and non-living things, places, events; *iconic* representations of people, living and non-living things, places and events (e.g., pictorial illustrations, film, video and audio recordings, computer graphics); and *abstract* representations of these entities (e.g., words and numbers in books, periodicals, and computers)

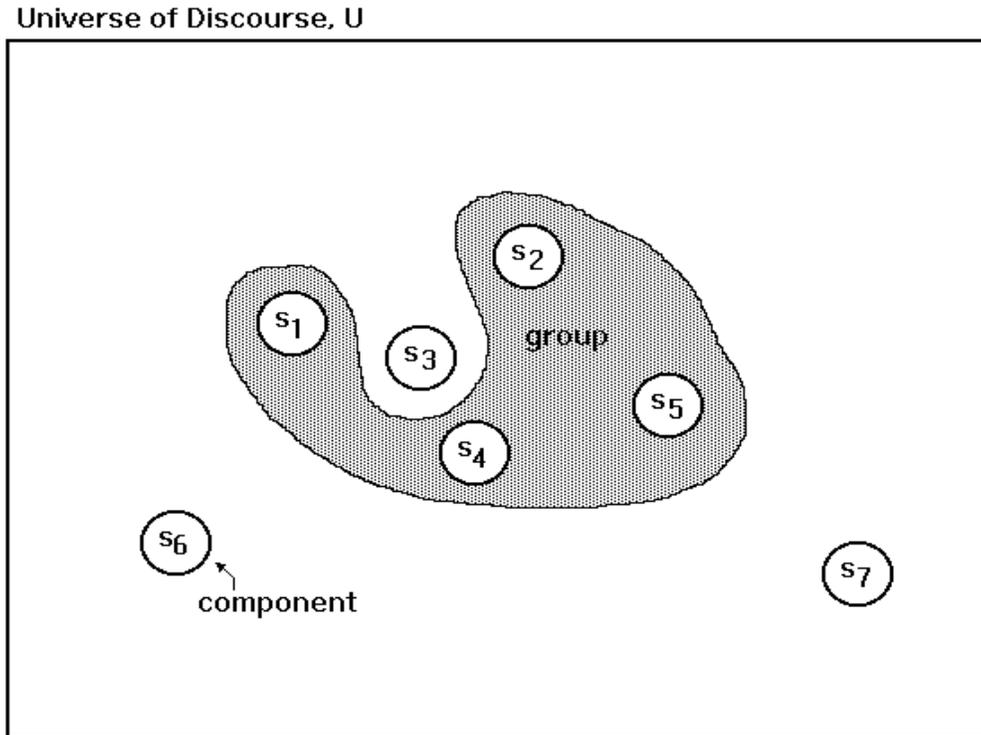


Figure 2: Set theoretic depiction of a group of components
(in the shaded area) in the Universe of Discourse

3. Group, S

- 3.1. "A group is at least two components that form a unit within the universe of discourse." (p. 40)
- 3.2. Analogous terms in set theory are 'set', 'elements', and the 'universal set'. In Figure 2, components s_1 , s_4 , s_2 and s_5 form a group. Components s_6 , s_3 and s_7 are not in the group.

4. Characterization, CH

- 4.1. This is a primitive term.
- 4.2. We can characterize things in many ways, normally by using 'signs' to refer to things, persons, places, events, etc. 'Signs' can be symbolic/abstract such as spoken or written words, but can also be icons, gestures, facial expressions, mime, demonstration by enactment, touch, etc. Some signs we use in education are 'teacher' (for one who guides the learning of another) and 'student' (for one

who is attempting to learn).

5. Information, I

- 5.1. "Information is a characterization of occurrences." (p. 40)
- 5.2. The notion of information is very specific here. "'Information', 'I', equals by definition 'characterization, CH, such that CH is equal to a set of categories, c, such that that probability distribution, p, such that the pair of c and the real number, v, (c,v), is an element of p'." (p. 40)
- 5.3. For example, suppose we have four categories of roles in education: teacher, student, administrator, and staff. Suppose in some education system we have 9 teachers, 11 administrators (parent volunteers, serving as a board of directors), 2 staff members and 150 students (total of 172 persons). We can compute relative frequencies to estimate the probability distribution of person-roles: $p(\text{teacher}) = 9/172 = .05$; $p(\text{administrator}) = 11/172 = .06$; $p(\text{staff}) = 2/172 = .01$; $p(\text{student}) = 150/172 = .87$.

Classification: Person-roles

	c_1 : teacher	c_2 : admin.	c_3 : staff	c_4 : student
Probability	.05	.06	.01	.87

5-1. Selective Information, I_s

- 5-1.1. "Selective information is information which has alternatives." (p. 40)
- 5-1.2. This means that there is uncertainty. Thus, there must be at least one category which has a probability that is not equal to zero or one. In the above example, this is true. The information about the set of person roles is $\{(\text{teacher},.05), (\text{administrator},.06), (\text{staff},.01), (\text{student},.87)\}$. There is uncertainty in the probability distribution. If we were to visit this school, the most likely person we would observe is a student. However, we will occasionally meet others such as teachers and parent board members. On the other hand, if every person was a student (probability = 1.0), then there is no selective information -- no uncertainty of category occurrences.

Classification: Person-roles (no uncertainty)

	c_1 : teacher	c_2 : admin.	c_3 : staff	c_4 : student
Probability	.00	.00	.00	1.00

We can measure degree of uncertainty in a probability distribution with H , from information theory. H is maximum when categories are equiprobable. H is minimum when one category has a probability of occurrence of one and all others zero.

Classification: Person-roles (maximum uncertainty)

	c_1 : teacher	c_2 : admin.	c_3 : staff	c_4 : student
Probability	.25	.25	.25	.25

5-1-1. Non-conditional Selective Information, I_{SN}

5-1-1.1. "Nonconditional selective information is selective information which does not depend on other selective information." (p. 41)

5-1-1.2. This is akin to the notion of independence in probability theory. Suppose we have two classifications: Person's Role and Ethnicity. Suppose our categories of ethnicity are: African-American, Anglo, Asian, Hispanic and Other. We could obtain a distribution of persons according to their ethnicity. If the $p(\text{Hispanic}) = a$, if the $p(\text{administrator}) = b$, if the $p(\text{Hispanic and administrator}) = a \square b$, and if this is true of all pairs of roles \square ethnicity, then we would say that the two probability distributions are *independent*. In other words, the role taken by a person does not depend on his or her ethnicity.

	c_{11} : teacher	c_{12} : admin.	c_{13} : staff	c_{14} : student	
c_{21} : Afr-Amer.	.010	.012	.002	.174	.200
c_{22} : Anglo	.025	.300	.005	.435	.500
c_{23} :					

Asian	.005	.006	.001	.087	.100
c_{24} : Hispanic	.010	.012	.002	.174	.200
c_{25} : Other	.000	.000	.000	.000	.000
	.050	.060	.010	.870	1.000

For example, the probability of being an Hispanic person and an administrator is 0.20×0.06 , which is equal to 0.012. The same is true for African Americans.

5-1-2. Conditional Selective Information, I_{SC}

- 5-1-2.1. "Conditional selective information is selective information which depends on other selective information." (p. 41)
- 5-1-2.2. In this case there is a statistical dependence. Each cell probability is no longer equal to the product of its marginal probabilities, as it is for non-conditional selective information. Notice for example in the table below that all administrators are Anglo. No administrators are from African-American, Asian, Hispanic or Other ethnic backgrounds.

	c_{11} : teacher	c_{12} : admin.	c_{13} : staff	c_{14} : student	
c_{21} : Afr-Amer.	.000	.000	.000	.200	.200
c_{22} : Anglo	.020	.060	.000	.420	.500
c_{23} : Asian	.000	.000	.000	.100	.100
c_{24} : Hispanic	.030	.000	.010	.150	.200
c_{25} : Other	.000	.000	.000	.000	.000
	.050	.060	.010	.870	1.000

Note that here the probability of being and African-American and an administrator is 0.000 (not 0.012 as above for non-conditional selective

information). If you are an African-American in this example, you are not going to serve in the role of teacher, administrator or staff but only as student. This is conditional selective information.

6. Transmission of Selective Information, $(I_{S1}, I_{S2}, \dots, I_{Si}, \dots, I_{Sn})$

6.1. "Transmission of selective information is a flow of selective information." (p. 42)

7. Affect Relation, R_A

7.1. "An affect relation is a connection of one or more components to one or more other components." (p. 42) In the below figure the affect relations are (s_7, s_6) , (s_1, s_4) , (s_1, s_2) , (s_1, s_5) , (s_4, s_2) , (s_4, s_5) , (s_2, s_5) , (s_5, s_2) ,

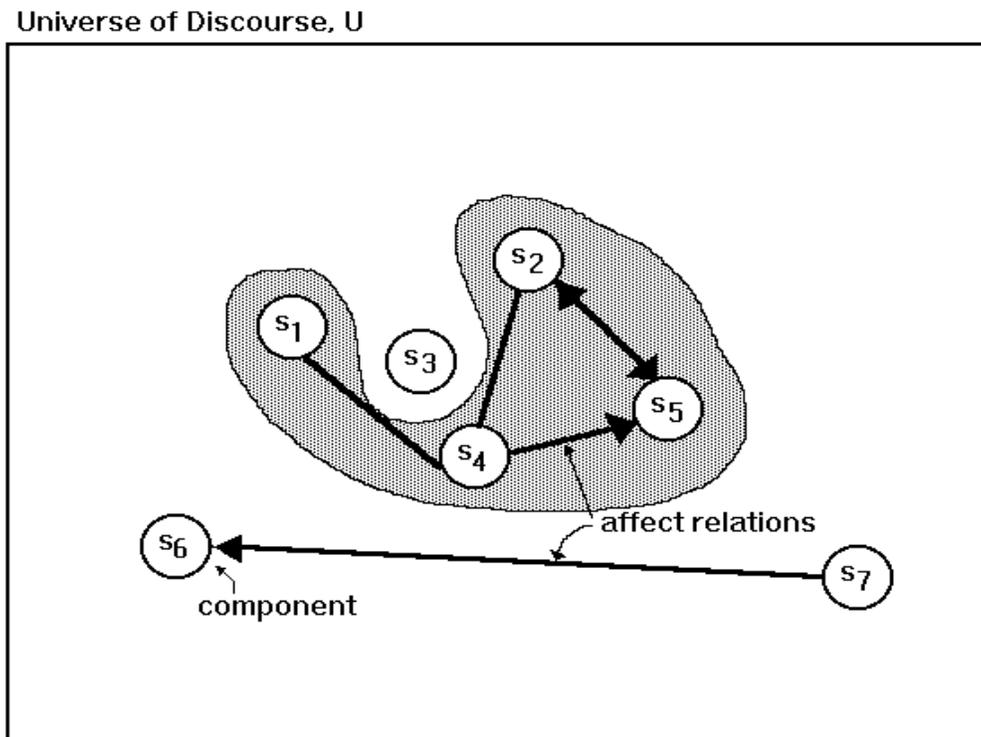


Figure 3: A graph theoretic depiction of relations among components

7-1. Directed Affect Relation, R_{DA}

- 7-1.1. "A directed affect relation is an affect relation in which one or more components have a *channel* to one or more other components." (p. 43)
- 7-1.2. In the above figure directed affect relations exist between (s_7, s_6) , (s_4, s_5) , (s_4, s_2) , (s_2, s_5) , and (s_5, s_2) .

7-1-1. Direct Directed Affect Relation, R_{DDA}

- 7-1-1.1. "A direct directed affect relation is a directed affect relation in which the *channel is through no other components*." (p. 43)
- 7-1-1.2. In the above figure the direct directed affect relations are: (s_7, s_6) , (s_4, s_5) , (s_2, s_5) , and (s_5, s_2) .

7-1-2. Indirect Directed Affect Relation, R_{IDA}

7-1-2.1. "An indirect directed affect relation is a directed affect relation in which the *channel is through other components.*" (p. 44)

7-1-2.2. In the above figure, the indirect directed affect relation is (s_4, s_2) . The channel is through s_5 .

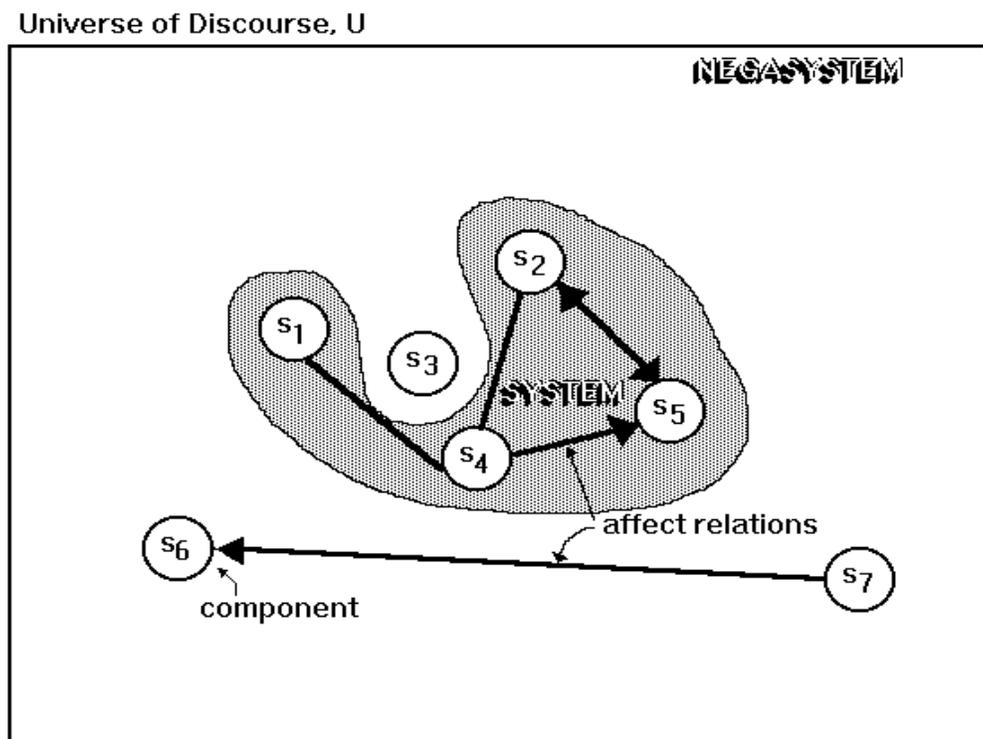


Figure 4: A set and graph theoretic depiction of a system (shaded set) and its negasystem (non-shaded complement) in the universe of discourse.

8. Educational System,

8.1. "A system is a group with at least one affect relation which has information." (p. 44)

In Figure 4, the shaded area represents a system, and the non-shaded area its negasystem.

8.2. Furthermore, Steiner (1988) has indicated that education must consist of teacher, student, content, and context subsystems. It seems to me that Steiner's notion of education identifies kinds of *relationships* which ought to occur in education (affect relations).

8.3. A *teacher* is one who guides the learning of another. This defines a kind of affect relation between two persons. Person A may guide the learning of Person B, and Person B may guide the learning of Person A. For example my wife of Irish descent has taught me to cook Chinese style dinners. I have given her guidance in using our computer at home. Furthermore, guidance of learning is not restricted to direct instruction (e.g., lecture, demonstrate, answer questions, ask questions). Learning may be guided indirectly as it is frequently in Montessori classrooms in which it occurs through interaction with the curriculum materials. Furthermore, the older students may guide younger students in Montessori classrooms in which mixed-age groups exist. These older peers act in the role of teacher (i.e., one who guides the learning of another). If teaching is viewed as an affect relation, then it unbinds us from thinking of teacher as a component in education. Teaching is a relationship between two persons, one of whom guides the other who follows.

8.4. A *student* is one who intends to learn through guidance from a teacher. In contrast, a learner is one who attempts to learn without guidance -- e.g., by trial-and-error. Studenting is also an affect relation that ought to occur in education. An undesirable kind of affect relation would be one who is being forced to learn against his or her will.

8.5. *Content* is that which is to be learned. There are both student-content and teacher-content affect relations. The kinds of student-content affect relations that we ought to create in education are cognitive, conative and affective. We want students to come to know the objects of learning (cognitive relationship with subject matter), to value such objects, and to associate positive feelings with the objects of learning. Subject matter need not be constrained to extant classifications such as mathematics, science, history, language arts, etc. The types of teacher-content affect relations can be similarly classified. Teachers should know the subject matter (and how to guide learning of subject matter, which is a further kind of understanding of content), value it, and love it.

8.6. *Context* is the setting in which guidance of learning occurs. When my wife helps me learn to cook, the context we work in is the kitchen. When I help her to use our computer, that usually occurs in the context of our home office area. Typical contexts of present-day, formal educational systems include classrooms in school buildings, principals, janitors, local school boards, furniture, black/white boards, overhead projectors, computers, books, libraries,

gymnasiums, school buses, cash, cafeterias, food, etc. Context could also include state departments of education, and national departments of education - if these are considered to be part of the education system. We have student-context, teacher-context, and content-context affect relations. When I am learning to cook, student-context relations include my reading a recipe from a book, observing my wife cook, chopping vegetables, measuring rice and water, etc. When my wife is learning to use a word-processor to make large-print words, student-context relations include her using a computer system and software program. (She makes curriculum materials for her pre-school Montessori classroom, which is a teacher-content relation.) There are also content-context affect relations. The object of learning may be symbolically represented through printed words in a book (e.g., a math textbook); the object of learning might be iconically represented through a videotape (e.g., a documentary on Martin Luther King); the object of learning might be physically present in the current setting (e.g., artifacts from an archeological dig; the city mayor herself).

9. Educational Negasystem,

- 9.1. "An educational negasystem is the components not taken to be in the education system." (p. 45)
- 9.2. Nowadays the negasystem would include the local community -- e.g., parents and other people, business, industry, local government. The universe of discourse could be extended to include state and national levels, or for that matter world-wide. If so, these would be part of the negasystem. Notice that the boundary between an education system and its negasystem does not have to be a physical boundary, in the sense of geographic space. For example, the local school board is normally part of a community's educational system. The board members are seldom physically present on school grounds. Nowadays, State Departments of Education are part of local educational systems in that they affect policies, practices, and financing. Those State Departments are physically remote but can be considered part of a local community's educational system. On the other hand, churches are not considered part of our public educational systems, and would be considered part of the negasystem as would business and industry.

10. Condition, F

- 10.1. Condition is a primitive term.

11. Educational System State, ST

- 11.1. "An educational system state is that system's conditions at a given time." (p. 45)

12. Educational Negasystem State, ST

- 12.1. "An educational negasystem state is that negasystem's conditions at a given time." (p. 46)

13. Educational System Property, P

- 13.1. "An educational system property is that system's conditions." (p. 46)

14. Educational Negasystem Property, P

- 14.1. "An educational negasystem property is that negasystem's conditions." (p. 46)

15. Value, V

- 15.1. This is a primitive term.

16. Educational System Property State, ST_P

- 16.1. "An educational system property state is that system property's value at a given time." (p. 47)
- 16.2. This notion of a property's value is referring to the value of some property of a system. Such properties are described below, such as toput, feedin, spillage, vulnerability, stability, etc. This is in contrast to the usual conception of property value as the financial worth of land and buildings in an economic system. The SIGGS notion of property state and value is much more general.

17. Educational Negasystem Property State, ST_P

- 17.1. "An educational negasystem property state is that negasystem property's value at a given time." (p. 47)

18. Educational System Environment, E

- 18.1. "Educational system environment is a negasystem of at least two components with at least one affect relation which has selective information." (p. 47)
- 18.2. Note that the environment of an educational system is also considered to be a system. See 8.1. above.

19. Educational Negasystem Environment, E

- 19.1. "Educational negasystem environment is a system with selective information." (p. 48)

20. Educational System Environmental Change, EC

- 20.1. "Educational system environmental change is a difference in educational system environment." (p. 48)

21. Educational Negasystem Environmental Change, EC

- 21.1. "Educational negasystem environmental change is a difference in educational negasystem environment." (p. 49)

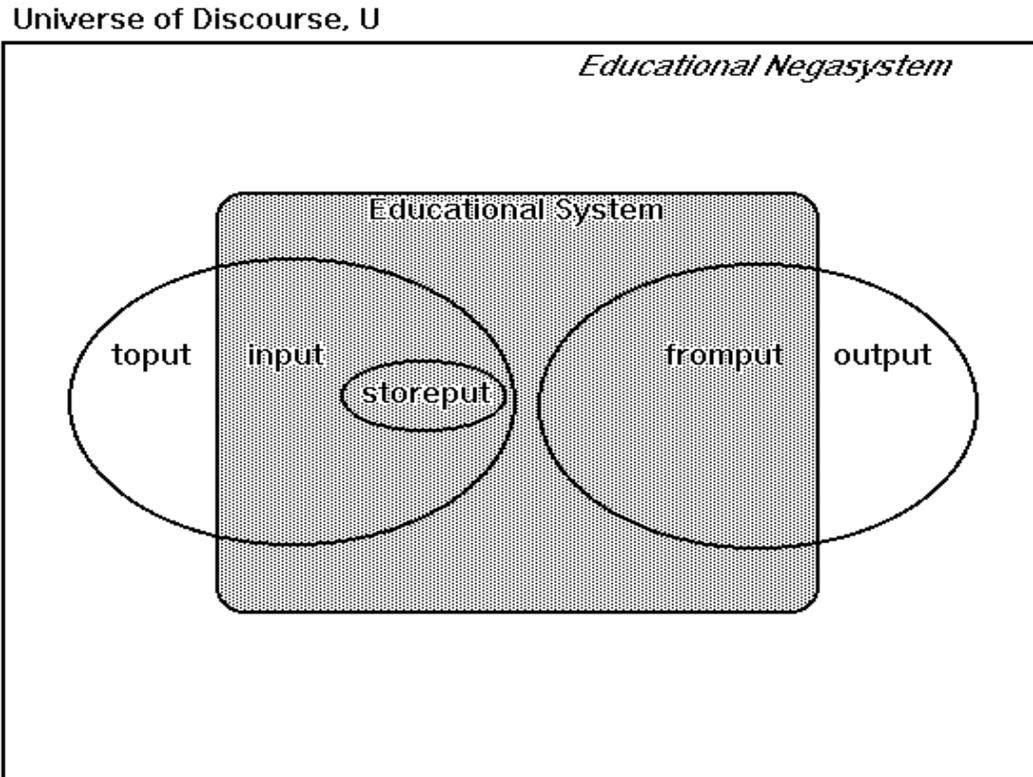


Figure 5: Information theoretic depiction of basic system properties: toput, input, storeput, fromput and output.

22. Educational System Toput, TP

- 22.1. "Educational system toput is educational system environment." (p. 49)
- 22.2. That is, toput is a negasystem of at least two components with at least one affect relation which has selective information.
- 22.3. Toput is the choice environment for an educational system -- i.e., what is available to choose from in the negasystem. For example, people are available in the educational system choice environment who are part of a social system. Some of those may be qualified as potential teachers in an educational system. Other people may available to the educational system as potential students, administrators and staff. Money, textbooks and computers may also be available in the educational system's choice environment (cf. Ackoff and Emery, 1972). Guns, gangs and drugs may also be educational system toput.

23. Educational System Input, IP

- 23.1. "Educational system input is an educational system with selective information." (p. 49)
- 23.2. After being taken into an educational system, teachers, students, administrators, textbooks and computers would be part of that system's input. Input is effectively what the system has selected from its choice environment. (Compare with feedin, 27, below.). If guns and drugs are kept out of schools, then they are toput which is not input.
- 23.3. The information is selective. (See 5-1. above.) At any given time there is uncertainty with respect to occurrences of kinds of students, teachers, administrators, textbooks, computers, guns, drugs, etc. that have been taken into an educational system.

24. Educational System Fromput, FP

- 24.1. "Educational system fromput is negasystem environment." (p. 50)
- 24.2. Fromput is the negasystem's toput, i.e., the choice environment of the negasystem. For example, an educational system may make available to society students who are literate and who value democracy. It may also make available broken computers, which need to be repaired. In higher education, an institution may make available new knowledge through disciplined inquiry. Educational systems make also make available students not wanted by society, e.g., those who have failed to learn what is needed to become a productive member of society, dropouts, or those who do not respect the rights of other human beings. Physical trash is another kind of educational system fromput: used paper, books, obsolete computers, garbage from school kitchens, etc.

25. Educational System Output, OP

- 25.1. "Educational system output is a negasystem with selective information." (p. 50)
- 25.2. Output is to negasystem as input is to system. Do not confuse output with feedout (see 28, below).
- 25.3. For example, business and industry may hire graduates of high schools. These graduates are outputs of the educational system when they are taken in by business and industry. Colleges and universities may admit high school graduates. When taken in by higher education, these students would have become outputs of local public and private education systems. Students who drop out of high school may become members of gangs. When taken in by these gangs, these students are outputs of the educational system.

26. Educational System Storeput, SP

- 26.1. "Educational system storeput is a system with input which is not fromput."
- 26.2. Storeput is not part of the negasystem's choice environment. storeput is conditional selective information (see 5-1-2 above). The condition here is that it is not fromput. Storeput is also selective information. There is uncertainty with respect to occurrences in the classifications of storeput.
- 26.3. When students are in school, they are usually not available to the educational negasystem (temporarily storeput). When they get on a bus at the end of the school day, then students would become fromput. When getting off the bus and entering home, then students would have become output. Nowadays computers are educational system storeput. They are not available for use in the educational negasystem (i.e., for students to take home like textbooks and homework assignments; for use by parents and local business during non-school hours). Another typical example of educational system storeput would be classroom furniture, science apparatus, student lockers, school buildings, etc.

27. Educational System Feedin, FI

- 27.1. "Educational system feedin is transmission of selective information from a negasystem to a system." (p. 51)
- 27.2. Feedin is a dynamic system property. When students get on the bus and enter school in the morning, this is educational system feedin. When schools purchase and install computer systems, this is educational system feedin. When schools buy textbooks and computer software, this is feedin. When money is collected from taxpayers and deposited in educational system bank accounts, this is feedin.
- 27.3. Note that Maccia and Maccia distinguish between toput, feedin, and input. The original notion of input in general systems theory could mean any or all of these three senses (toput, feedin, input). In the SIGGS theory, input is taken only as a system with selective information. Toput is the system's choice environment, and feedin is the process through which toput becomes input.

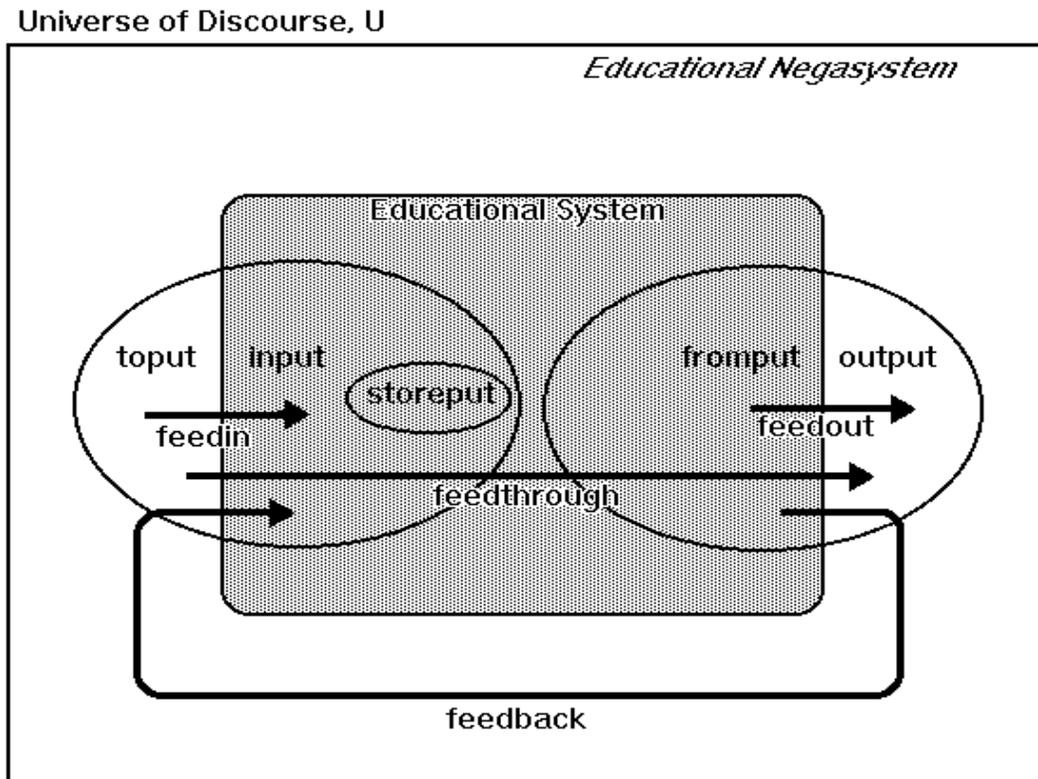


Figure 6: Information theoretic depiction of flow between an educational system and its negasystem.

28. Educational System Feedout, FO

- 28.1. "Educational system feedout is transmission of selective information from a system to a negasystem." (p. 51)
- 28.2. Educational system feedout is equivalent to negasystem feedin.
- 28.3. When teachers receive their paychecks and deposit the money into their personal bank accounts, or spend it on food, shelter, entertainment, etc., this is educational system feedout. When the garbage collectors come and haul the trash away, this is feedout. When students graduate from high school and enter college or get jobs in society, this is feedout. When students leave school at the end of the day and go home, this is feedout, and likewise of course for teachers, administrators, and other personnel.

29. Educational System Feedthrough, FT

- 29.1. "Educational system feedthrough is transmission of selective information from

a negasystem through a system to a negasystem." (p. 51)

- 29.2. Feedthrough is feedin, then feedout. Some refer to this as throughput.
- 29.3. Some examples of educational systems feedthrough: Students, teachers, administrators and staff come to school at the beginning of the day (FI) and then go home and the end of the school day (FO). Tax money is taken in and deposited in educational system bank accounts (FI). It is then distributed as salaries to teachers and staff, and deposited in their bank accounts or spent in the local community on personal needs for food, shelter, entertainment, etc. (FO)

30. Educational System Feedback, FB

- 30.1. "Educational system feedback is transmission of selective information from a system through a negasystem to a system." (p. 51)
- 30.2. Feedback is educational system feedout, then feedin. Note that educational system feedback is equivalent to negasystem feedthrough.
- 30.3. Examples of feedback: Students take textbooks and assignments home at the end of the school day (FO), do their assignments, and return them to their teachers when they come to school the next day (FI). Teachers and other school staff pay taxes on income from school salaries (FO), and some of this tax money is taken in by the educational system for its operating capital (FI). Some students graduate from high school and enter college (FO), prepare to become teachers in college, and then are hired as teachers by local educational systems (FI). Students graduate from high school (FO), get married and have children. When those children are old enough, they are admitted as students in the educational system (FI). Students leave school with inadequate skills, knowledge and attitudes (FO), become destitute and try to raise families in poverty. Their impoverished, malnourished and underdeveloped children are admitted as students to the educational system in a special education program (FI). These examples of feedout subsequently followed by feedin are instances of educational system feedback.

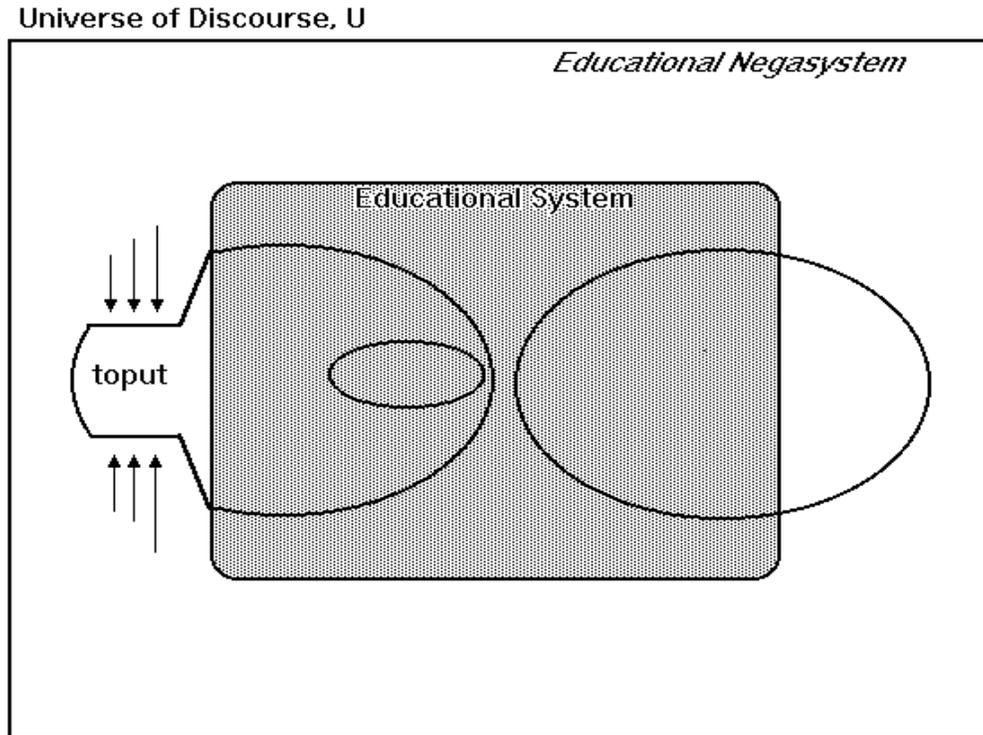


Figure 7: Educational system filtration is restriction in its choice environment (toput is less than maximum).

31. Educational System Filtration, FL

- 31.1. "Educational system filtration is restriction of system environment." (p. 52)
- 31.2. Filtration is, in other words, restriction of educational system toput. Toput is the environment of an educational system, which is a negasystem of at least two or more components with at least one affect relation which has selective information. Filtration is a property of the negasystem.

- 31.3. A typical example of educational system filtration is that state textbook adoption agencies restrict the availability of textbooks from which local schools can choose. Furthermore, state adoption committees in Texas, California, and New York act as significant filters of textbooks published in general. Another example of filtration is that not all people are eligible as students in the public education system. Typical state policy restricts that only those students who are between the ages of 5 and 18 are made available to the educational system. Not all content is made available for selection by educational systems. Societal values restrict the availability of pornographic materials as subject matter. Similarly, information for potential sex education in school is restricted by community mores.

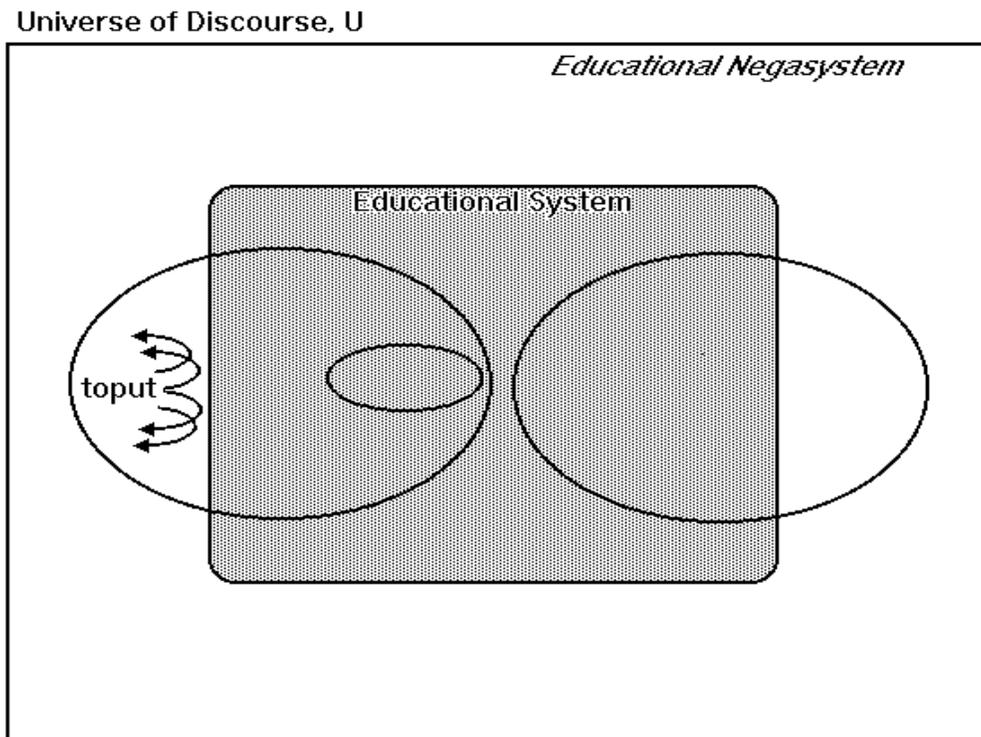


Figure 8: Educational system spillage (restriction of feedin).

32. Educational System Spillage, SL

- 32.1. "Educational system spillage is restriction in feedin." (p. 52)
- 32.2. Spillage is toput that does not become input. For example, prior to Public Law

94-142, some handicapped people were not allowed to attend public school. Hence, they were spillage. Another example is that over 10,000 people apply to Harvard University each year, but about only 2,000 are admitted as students. The remaining 8,000 are spillage at Harvard University. Some students try to bring drugs and guns to school. If the guns and drugs are not allowed to enter school grounds and buildings, then they become spillage. If parents attempt to send notes to their children's teachers, but those notes get lost on the way to school, then the parent's messages are spillage. Many people and organizations send me electronic mail. I only have time to read some of the messages. Those messages which I do not read are spillage (toput that is not input).

33. Educational System Regulation, RG

- 33.1. "Educational system regulation is adjustment of fromput." (p. 52)
- 33.2. From the point of view of the negasystem, system regulation is the equivalent to filtration from the point of view of the system. In terms of information theory, regulation is the difference between the value of maximum fromput and current fromput. Fromput is maximum when the categories of alternatives are equally likely to occur.

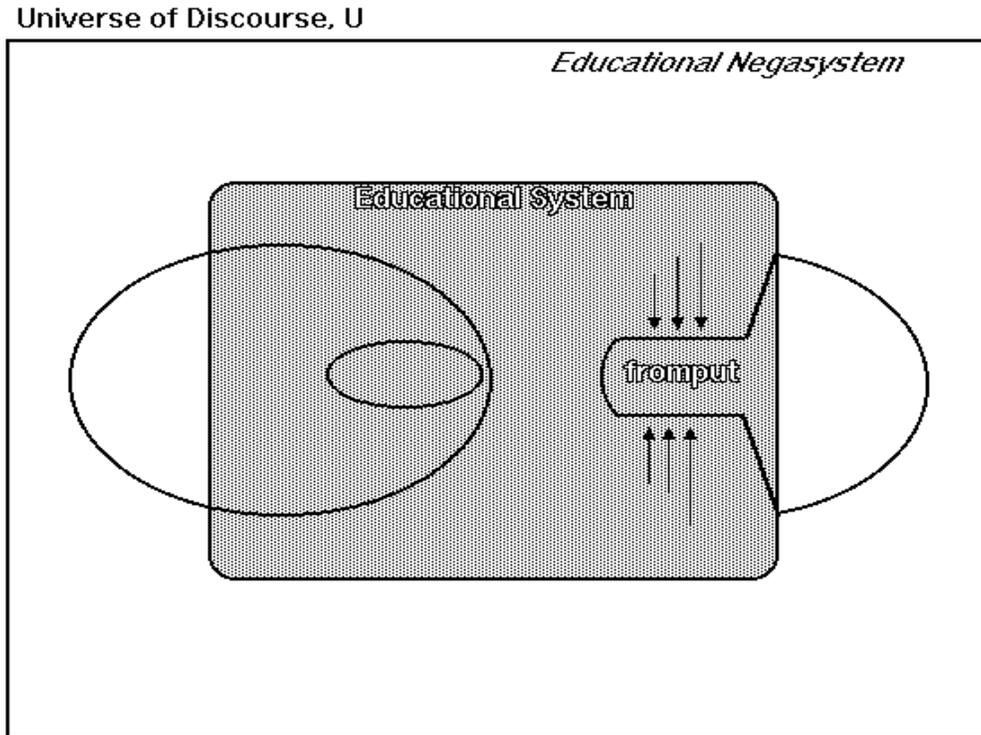


Figure 9: Educational system regulation is adjustment (restriction) of fromput.

- 33.3. A typical example of regulation in the public school system is that students must complete 12 grades before being allowed to graduate. Only students with diplomas (fromput) become available for selection by the negasystem (e.g., by colleges, business and industry). This is a kind of educational system regulation. A further example would be to establish competency levels in a variety of subject matter areas. Currently students are allowed to graduate from high school when they have passed a minimum number of courses with varying degrees of mastery. If instead, they were only allowed to graduate when they were able to demonstrate a high level of mastery in all important subjects, then this would reduce the uncertainty in the fromput distribution. The likelihood would much be lower for the occurrence of incompetent high school graduates who are made available to business and industry, higher education, and society in general. Conversely the likelihood of competent graduates would be substantially higher. Thus, uncertainty would be reduced

in educational system fromput.

34. Educational System Compatibility, CP

- 34.1. "Educational system compatibility is commonality between feedin and feedout." (p. 53)
- 34.2. In information theory a B measure is used to determine 'common information ... at the pair of feedin and feedout.' (p. 53)

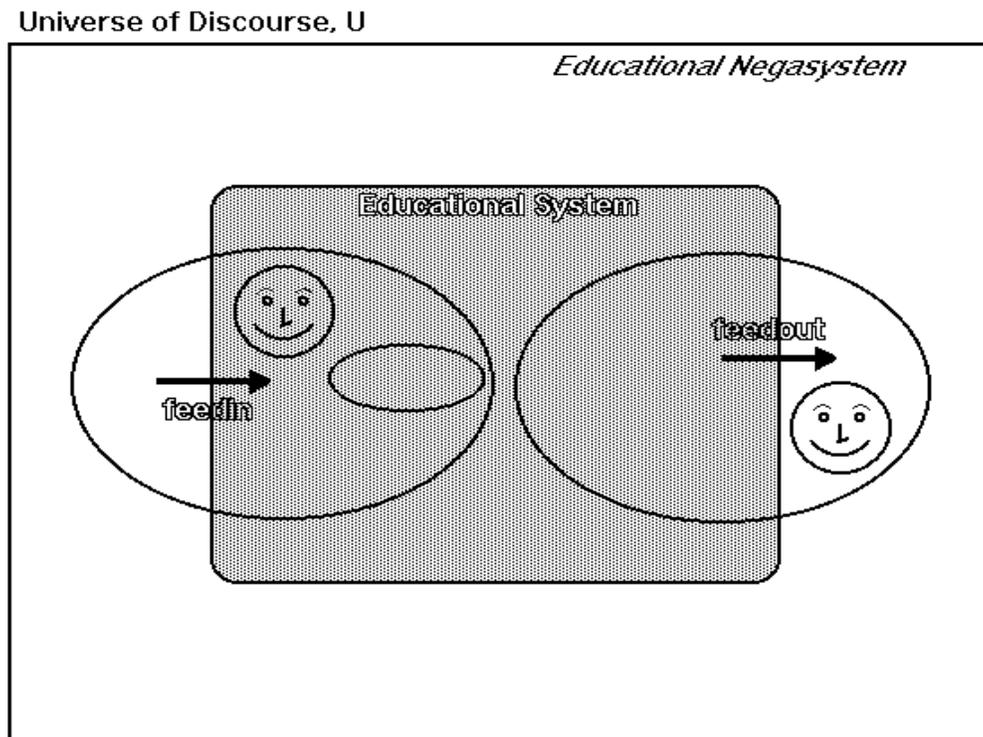


Figure 10: Compatibility between and educational system and its negasystem occurs when there is commonality between feedin and feedout.

- 34.3. An example of high compatibility is when society provides students to the educational system who are ready to learn (i.e., who are physically healthy, developmentally capable, and value education). When the educational system takes them in at age 5 or 6, this is feedin. When students graduate from high school, they have the knowledge, skills and attitudes that society wants (feedout). In this case, compatibility is high: the negasystem makes available the kinds of students wanted by the educational system; the educational system

makes available the kinds of students wanted by the negasystem. An example of low compatibility is when society provides students who do not want to learn, who do not value their education. Public schools must take them in. During school these students experience failure and humiliation. These students may become trouble-makers and get expelled from school, they may drop out, or they may just "get by" with barely passing grades. In any case, they do not have the knowledge, skills and attitudes wanted by society. In this situation compatibility between the educational system and its negasystem is low.

35. Educational System Openness, O

- 35.1. "Educational system openness is feedin and/or feedout." (p. 53)
- 35.2. 'Openness', 'O', equals by definition 'feedin state, ST_{FI} , plus feedout state, ST_{FO} , minus compatibility state, ST_{CP} , is equal to a real number, δ '. (p. 53)
- 35.3. A closed system is one in which there is no feedout and no feedin. See Figure 11. It is hard to imagine a closed educational system with respect to no feedin and no feedout of people (who act as students, teachers and staff). Perhaps it is easier to imagine an educational system that is closed with respect to content goals. That is, such a system does not accept new learning goals demanded by society (e.g., computer competence, cooperative teamwork skills) and does not provide society with student graduates who have achieved these new learning goals. An open system has at least some feedin or some feedout or both. See Figure 6.

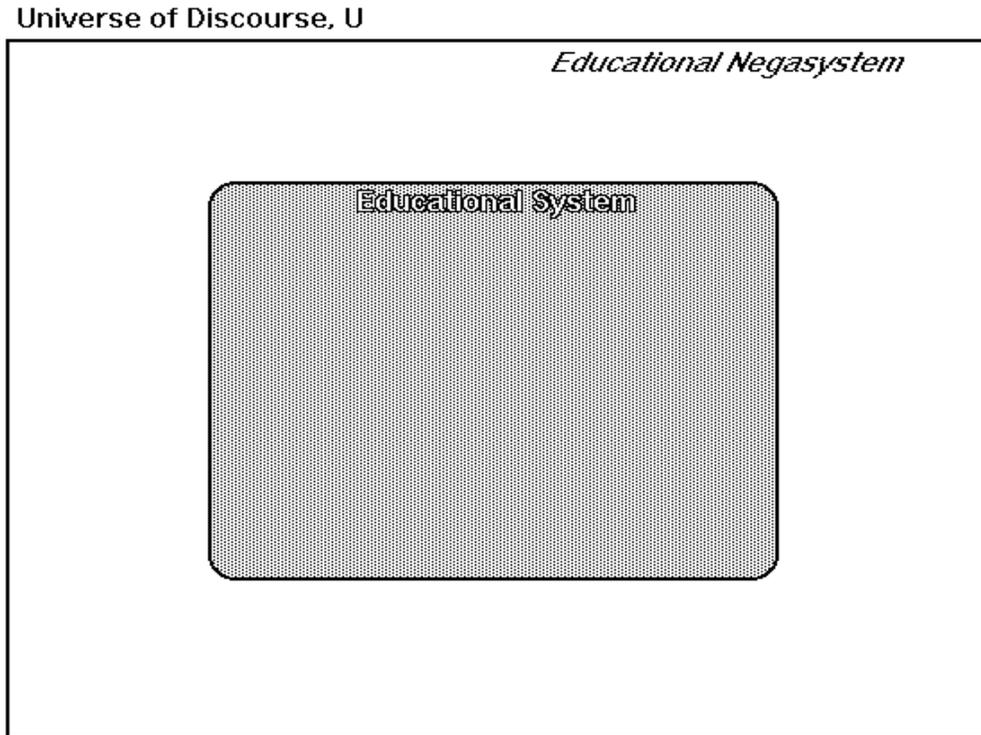


Figure 11: A closed educational system (no feedin or feedout).

- 35.4. Technically, openness can be measured operationally by a T measure in information theory (for FI and FO respectively) and a B measure for compatibility.
- 35.5. For example, suppose that students were distributed in the choice environment (toput) according to ability level such that $p(\text{high ability}) = .15$, $p(\text{medium ability}) = .50$, and $p(\text{low ability}) = .35$. In school A the distribution of ability level in terms of students admitted (input) is $p(\text{high ability}) = 1.00$, $p(\text{medium ability}) = 0.00$ and $p(\text{low ability}) = 0.00$. In school B, the distribution of ability level in terms of students admitted (input) is $p(\text{high ability}) = .20$, $p(\text{medium ability}) = .60$, and $p(\text{low ability}) = .20$. All other things equal, it can be seen that school B is more open with respect to feedin of students of varying ability levels. School A is less open in that it admits only students of high ability. Hence there is more spillage of medium and low ability students in school A.

36. Educational System Adaptability, AD

- 36.1. "Educational system adaptability is difference in compatibility under system environmental change." (p. 53)

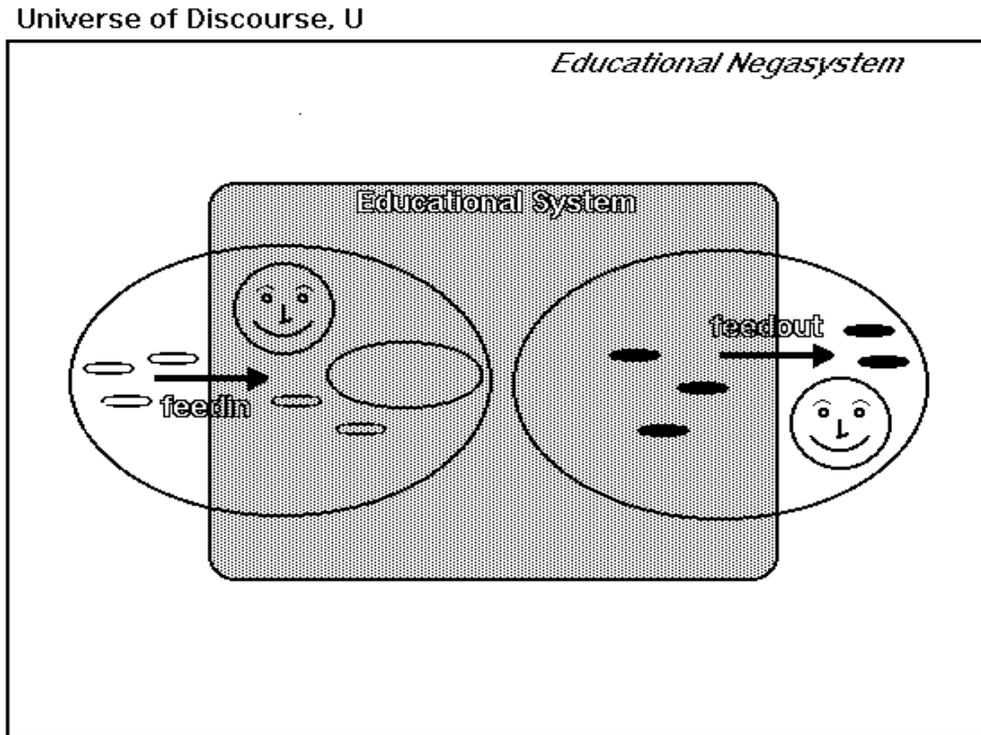


Figure 13: At time 2, some input becomes the system (feedin). At time 3 and 4, some output becomes output (feedout). Compatibility is now higher.

- 36.2. For example, suppose at one time there is an educational system which contains no computers, no opportunities for students and teachers to learn to use computers, and no students who graduate with computer skills and knowledge. Then at a later time computers are invented and become useful in business, industry, government, military and other social institutions, and social expectations arise that students should learn to use computers in school (environmental change). At this point in time compatibility is low. Societal demands for schools to teach students how to use computers go essentially unheeded, and those students who do graduate with computer competence do so despite their educational system (e.g., learn on their own at home or elsewhere). Now suppose that an educational system begins to hire new

teachers with computer competence, to buy computer hardware and software, and to create facilities for networking and housing the equipment. This would be a change in feedin, which is half of the compatibility notion. Now suppose further that students and teachers begin using computers extensively in schools, and that students begin to graduate who now have the computer competencies that are wanted by society. This would be a change in feedout, which is the other half of the compatibility notion. Now compatibility between the educational system and negasystem is higher. This whole process, beginning with a change in the educational system environment (see Figure 12), and the subsequent changing of educational system compatibility, is an example of educational system adaptability (see Figure 13).

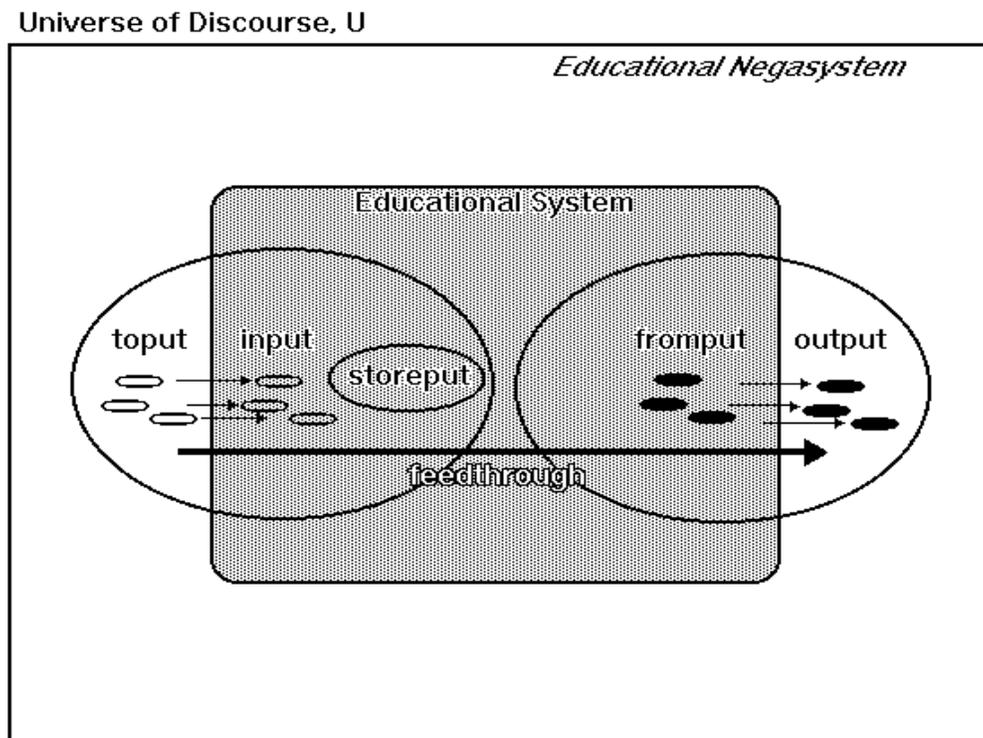


Figure 14: A highly efficient educational system.

37. Educational System Efficiency, EF

37.1. "Educational system efficiency is commonality between feedthrough and

toput." (p. 53)

- 37.2. Feedthrough is feedin at time 1 and feedout at time 2. Toput is the educational system choice environment. Thus system efficiency is commonality between what is made available to the system for selection, and what the system then takes in and what the negasystem then takes out from what the system makes available.
- 37.3. In Figure 14 a highly efficient educational system is depicted. All of what is made available is fed in by the system, and all of what the system makes available is fed out. A system would be less efficient if some of the toput does not become input, and some of the fromput does not become output. For example, suppose that 500 students apply for admission to an educational system, but only 50 are admitted who have the highest SAT scores. Of those 50, some drop out during their educational program. Then at some time later, 35 students finish their program and graduate. Of those 35, 20 students find jobs and the remainder join the ranks of the unemployed. In this case, we would say the educational system is less efficient.

38. Educational System Complete Connectedness, CC

- 38.1. "Educational system complete connectedness is every two components directly channeled to each other with respect to affect relations." (p. 54)
- 38.2. For example, if the affect relation is 'guiding the learning of another' then an educational system would be completely connected with respect to this kind of affect relation if every person taught every other person. In Figure 15 it can be seen that not all pairs of components are completely connected. Those pairs which do have the property, CC, are (s_1, s_3) and (s_4, s_6) . The total number of possible pairwise connections is $n(n-1)/2$. In this case there are $8 \times 7 / 2 = 28$ possible pairs. The degree of complete connectedness in Figure 15 is $2/28 = 0.071$.

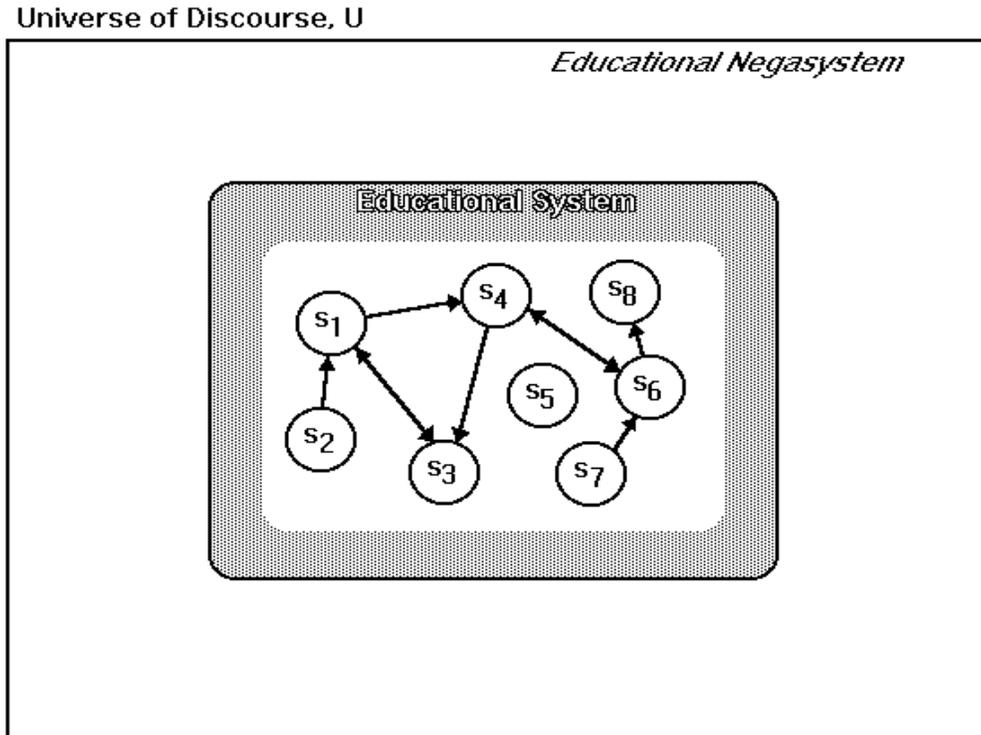


Figure 15: A depiction of various kinds of connectedness for the affect relation, 'guiding the learning of another', among components $s_1 \dots s_8$.

39. Educational System Strongness, SR

- 39.1. "Educational system strongness is not complete connectedness and every two components are channeled to each other with respect to affect relations." (p. 54)
- 39.2. When two components have the property strongness, both can affect each other, but at least one of the connections is indirect. In Figure 15, there are four strongly connected pairs of components with respect to the affect relation, 'guiding the learning of another': (s_1, s_4) , (s_1, s_6) , (s_3, s_4) and (s_3, s_6) . For example, s_1 can directly guide s_4 , but s_4 's guidance of s_1 is indirect. The degree of strongness in Figure 15 is $4/28 = 0.143$.

40. Educational System Unilateralness, U

- 40.1. "Educational system unilateralness is not either complete connectedness or

strongness and every two components have a channel between them with respect to affect relations." (p. 55)

- 40.2. In a unilateral affect relation either x can affect y or y can affect x , but not both. In Figure 15, there are 14 unilateral affect relations: (s_1, s_2) , (s_1, s_7) , (s_1, s_8) , (s_2, s_3) , (s_2, s_4) , (s_2, s_6) , (s_2, s_8) , (s_3, s_7) , (s_3, s_8) , (s_4, s_7) , (s_4, s_8) , (s_6, s_7) , (s_6, s_8) and (s_6, s_8) . The degree of unilateralness with respect to 'guiding the learning of another' in Figure 15 is $14/28 = 0.50$.

41. Educational System Weakness, WE

- 41.1. "Educational system weakness is not either complete connectedness or strongness or unilateralness and every two components are connected with respect to affect relations." (p. 55)
- 41.2. When two components are weakly connected, there is no channel between them, but one can get from one to the other by ignoring the direction of the arrows. In Figure 15 the affect relation (s_2, s_7) has the property of weakness. The only way to get from s_2 to s_7 is to ignore the arrow from s_7 to s_6 . The degree of weakness with respect to the affect relation, 'guiding the learning of another', is $1/28 = 0.036$.

42. Educational System Disconnectedness, DC

- 42.1. "Educational system disconnectedness is not either complete connectedness or strongness or unilateralness or weakness, and some components are not connected with respect to affect relations." (p.55)
- 42.2. In Figure 15 the following pairs of components have the property of disconnectedness: (s_1, s_5) , (s_2, s_5) , (s_3, s_5) , (s_4, s_5) , (s_6, s_5) , (s_7, s_5) , and (s_8, s_5) .

It should be noted that affect relations can be of many kinds. I have used the 'guidance of the learning of another' relationship in the examples above for sake of simplicity and continuity. Other kinds of relationships can be characterized such as ' S_i tries to learn C_i ', ' S_i respects S_j as a unique individual', 'content component C_i is embodied by context component X_i ', ' S_i values C_i ', etc. For *each* kind of affect relation we can draw a digraph as in Figure 15. The kinds of connectedness are given in the table below for the affect relation, 'guiding the learning of another', (also depicted graphically in Figure 15). Note that CC = complete connectedness, SR = strongness, U = unilateralness, WE = weakness, and DC = disconnectedness.

	s ₁	s ₂	s ₃	s ₄	s ₅	s ₆	s ₇	s ₈
s ₁	--	--	--	--	--	--	--	--
s ₂	U	--	--	--	--	--	--	--
s ₃	CC	U	--	--	--	--	--	--
s ₄	SR	U	SR	--	--	--	--	--
s ₅	DC	DC	DC	DC	--	--	--	--
s ₆	SR	U	SR	CC	DC	--	--	--
s ₇	U	WE	U	U	DC	U	--	--
s ₈	U	U	U	U	DC	U	U	--

Note: add discussion here of properties of entire digraphs, not pairs of relations as above. E.g., a completely connected digraph, a strong one, etc.

43. Educational System Vulnerability, VN

- 43.1. "Educational system vulnerability is some connections when removed produce disconnectivity with respect to affect relations." (p. 56)
- 43.2. In Figure 15, it can be seen that if the pair affect relation (s₂,s₁) is removed, then s₂ would then become disconnected from the others. Similarly, if the affect relation (s₇,s₆) is removed, then component s₇ would become disconnected. The same is true for the relation (s₆,s₈) for component s₈.

44. Educational System Passive Dependence, D_P

- 44.1. "Educational system passive dependence is components which have channels to them." (p. 56)
- 44.2. In Figure 15 the set of components which have the property passive dependence = {s₁, s₃, s₄, s₆, s₈}. Thus the degree of passive dependence is 5/8 = 0.625.

45. Educational System Active Dependence, D_A

- 45.1. "Educational system active dependence is components which have channels from them." (p. 57)

- 45.2. In Figure 15 the set, $\{s_1, s_2, s_3, s_4, s_6, s_7\}$. The degree of active dependence is $6/8 = 0.75$.

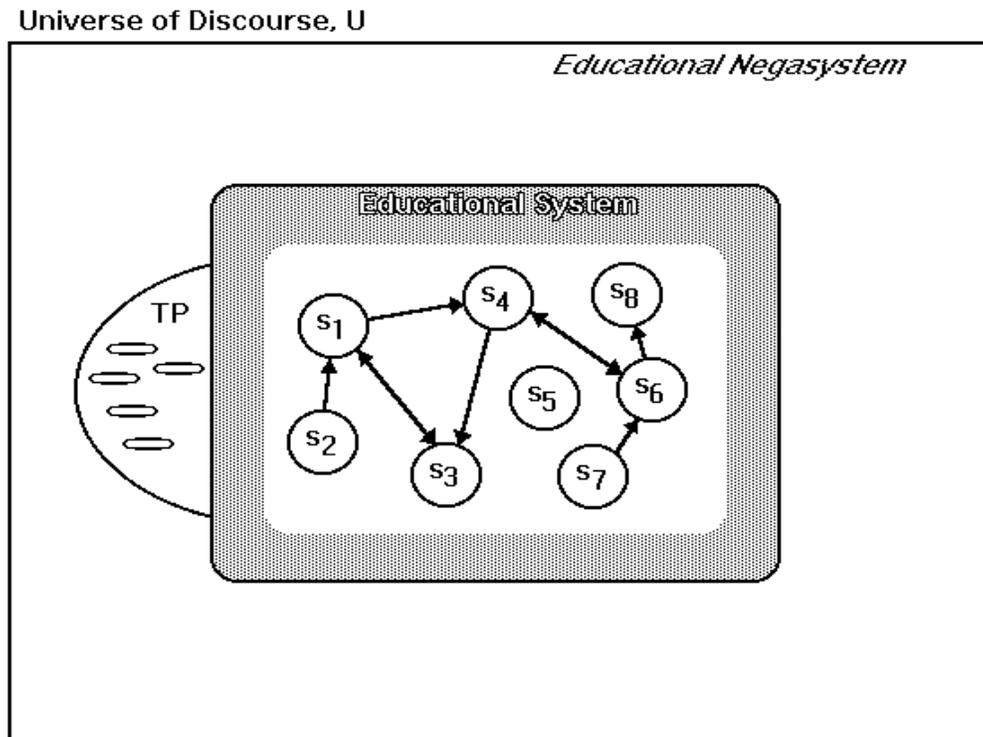


Figure 16: At time 1, the system looks like this. Components s_2 and s_7 are independent.

46. Educational System Independence, I

- 46.1. "Educational system independence is components which do not have channels to them." (p. 57)
- 46.2. Note that in the predicate calculus definition of independence it is evident that independent components may or may not have channels from them. However, independent components cannot have channels to them. In both Figures 15 and 16, the set of components which has the property of independence is $\{s_2, s_5, s_7\}$.

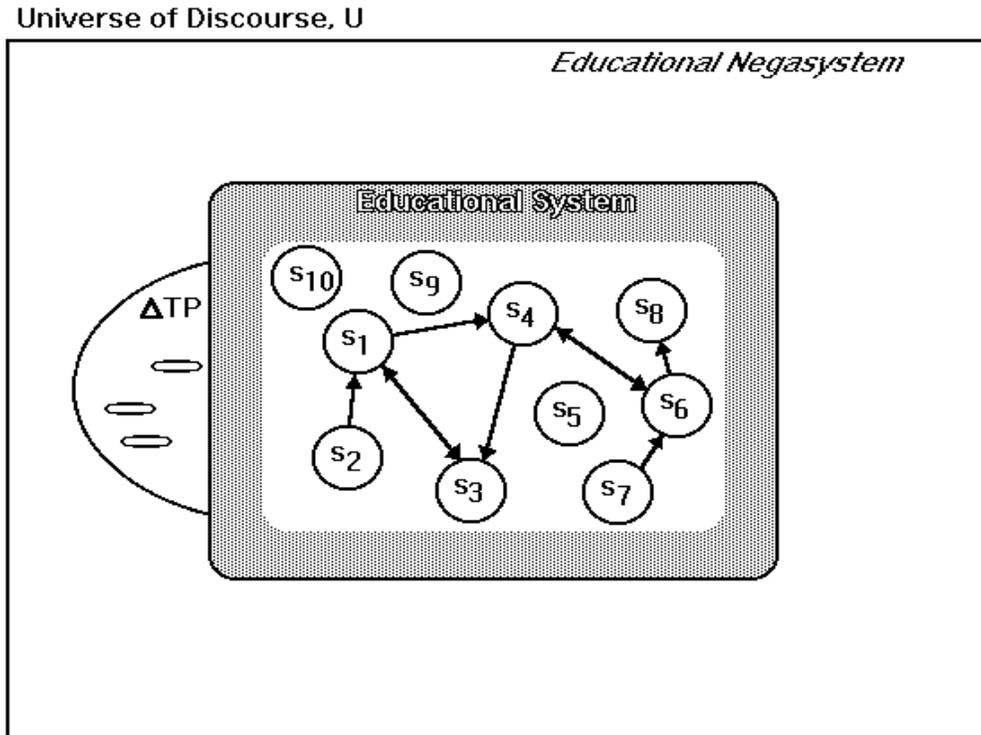


Figure 17: At time 2, topout has changed (components s_9 and s_{10} were fed in), but independence has not changed.

47. Educational System Segregation, SG

- 47.1. "Educational system segregation is (maintenance of) independence under system environmental change." (p. 57)
- 47.2. System environmental change means that at time 1, the state of topout was at one value; then at time 2, the topout state changed. Compare Figures 16 and 17. During this environmental change, the value of the independence state of the system did not change. The system property of independence at time 1 was $\{s_2, s_5, s_7\}$. System independence did not change at time 2.

48. Educational System Interdependence, ID

- 48.1. "Educational system interdependence is components which have channels to and from them." (p. 57)
- 48.2. In Figure 17, the components which have both channels to and from them comprise the set, $\{s_1, s_3, s_4, s_6\}$

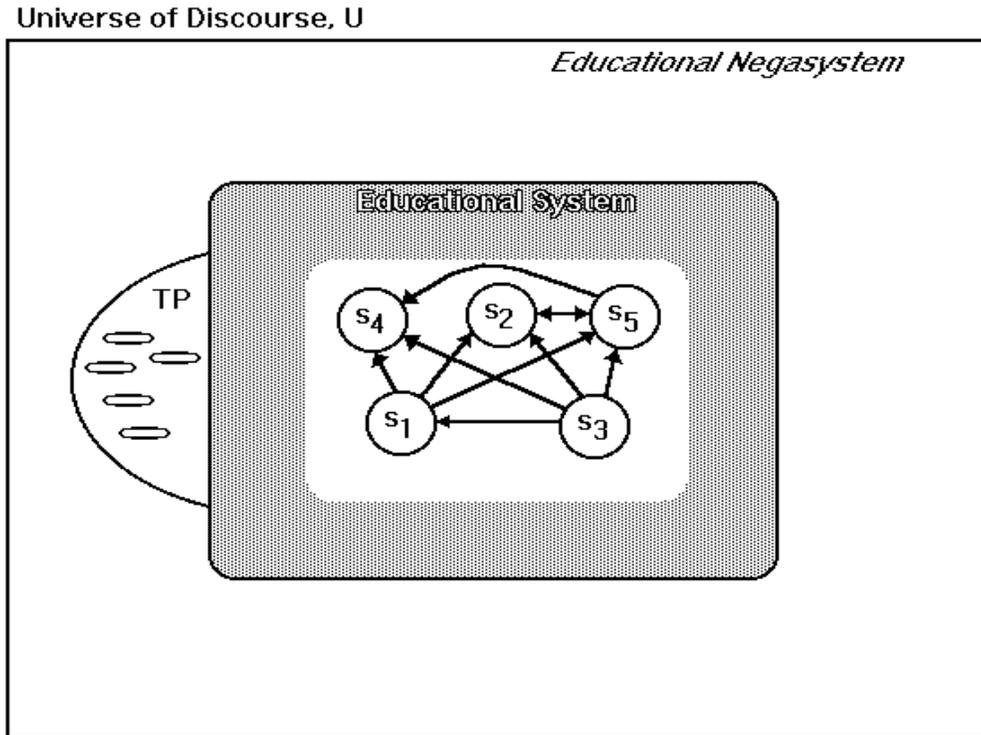


Figure 18: At time 1, component s_3 has the property of wholeness (i.e., which has channels to all other components).

49. Educational System Wholeness, W

- 49.1. "Educational system wholeness is components which have channels to all other components." (p. 58)
- 49.2. In Figure 18 the set of components which have channels to all other components is $\{s_3\}$. For example, if the affect relation is 'guiding the learning of another', then s_3 has the property wholeness with respect to this affect relation.

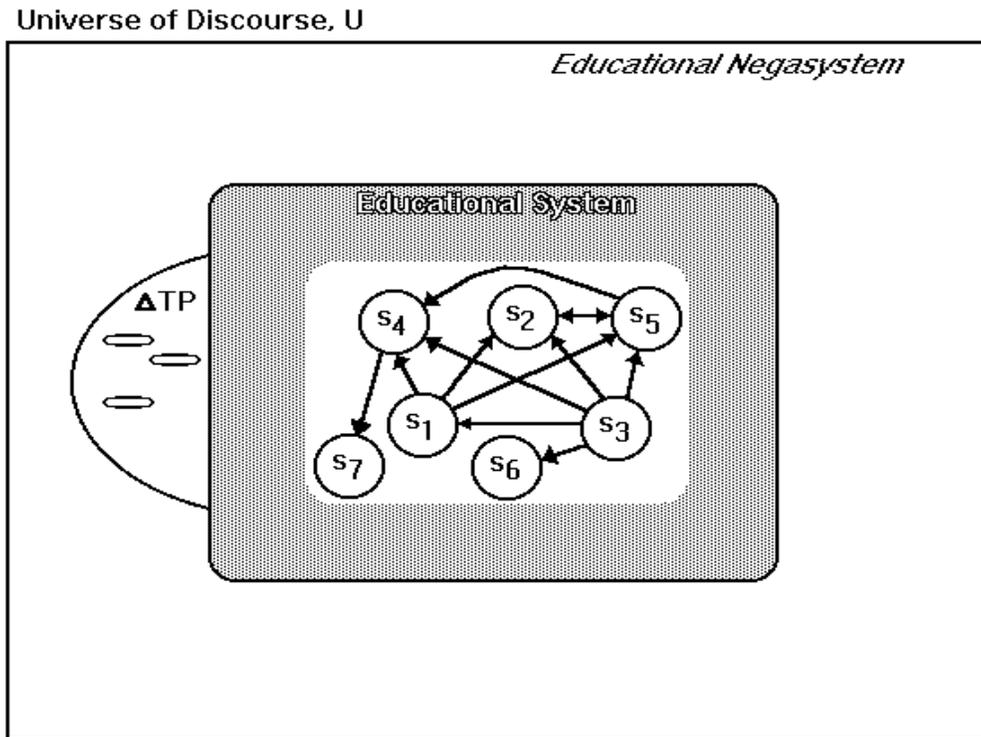


Figure 19: At time 2, toput has changed. Components s_6 and s_7 have been taken into the system. Wholeness is still maintained in that s_3 still has channels to all other components.

50. Educational System Integration, IG

- 50.1. "Educational system integration is (maintenance of) wholeness under system environmental change." (p. 58)
- 50.2. In Figures 17 (time 1) and 18 (time 2) the system environment has changed. Two components were fed into the system. Wholeness is still maintained. Component s_3 still has channels to all other components (e.g., with respect to the affect relation, 'guiding the learning of another'). Note that the channel from s_3 to s_6 is direct and from s_3 to s_7 is indirect.

51. Educational System Hierarchical Order, HO

- 51.1. "Educational system hierarchically order is levels of subordinateness with components in each level with respect to affect relations." (p. 58)

51.2.

52. Educational System Flexibility, F

52.1. "Educational system flexibility is different subgroups of components through which there is a channel between two components with respect to affect relations." (p. 59)

53. Educational System Homomorphism, HM

53.1. "Educational system homomorphism is components having the same connections as other components." (p. 60)

54. Educational System Isomorphism, IM

54.1. "Educational system isomorphism is components having the same connections as other corresponding components." (p. 60)

55. Educational System Automorphism, AM

55.1. "Educational system automorphism is components whose connections can be transformed so that the same connections hold." (p. 61)

56. Educational System Compactness, CO

56.1. "Educational system compactness is average number of direct channels in a channel between components." (p. 62)

57. Educational System Centralization, CE

57.1. "Educational system centralization is concentration of channels." (p. 62)

58. Educational System Size, SZ

58.1. "Educational system size is number of components." (p. 62)

59. Educational System Complexity, CX

59.1. "Educational system complexity is the number of connections." (p. 62)

60. Educational System Selective Information, SI

60.1. "Educational system selective information is the amount of selective information." (as defined by the H measure in information theory, p. 63)

61. Educational System Size Growth, ZG

61.1. "Educational system size growth is increase in size." (p. 63)

62. Educational System Complexity Growth, XG

62.1. "Educational system complexity growth is increase in complexity." (p. 63)

63. Educational System Selective Information Growth, TG

63.1. "Educational system selective information growth is increase in selective information." (p. 63)

64. Educational System Size Degeneration, ZD

64.1. "Educational system size degeneration is decrease in size." (p. 64)

65. Educational System Complexity Degeneration, XD

65.1. "Educational system complexity degeneration is decrease in complexity." (p.64)

66. Educational System Selective Information Degeneration, TD

66.1. "Educational system selective information degeneration is decrease in selective information." (p. 64)

67. Educational System Stability, SB

67.1. "Educational system stability is no change with respect to conditions." (p. 64)

68. Educational System State Steadiness, SS

68.1. "Educational system state steadiness is stability under system environmental change." (p. 65)

69. Educational System State Determination, SD

69.1. "Educational system state determination is derivability of conditions from one and only one state." (p. 65)

70. Educational System Equifinality, EL

70.1. "Educational system equifinality is derivability of conditions from other states." (p. 65)

71. Educational System Homeostasis, HS

71.1. "Educational system homeostasis is equifinality under system environmental change." (p.66)

72. Educational Negasystem Stress, SE

72.1. "Educational system stress is change beyond certain limits of negasystem state." (p. 66)

73. Educational System Strain, SA

73.1. "Educational system strain is change beyond certain limits of system state." (p. 67)

SIGGS Educational System Hypotheses

Maccia and Maccia (1966), pp. 138 - 167.

(Note that their theory was for school systems. I have taken the liberty of substituting 'educational system' for school system in the hypotheses below. Also, I do not include hypotheses specific to Maccia and Maccia's typologies of affect relations (referent, legitimate, instructional, governance, facilitating, etc. T.W.F., 1/2/95)

1. If educational system environmental change increases, then change in educational system input is greater than some value.
2. If educational system environmental change increases, then change in fromput is greater than some value.
3. If educational system environmental change increases, then change in feedback is greater than some value.
4. If educational system environmental change increases, then change in filtration is greater than some value.
5. If educational system toput increases, then input increases to some value and then decreases.
6. If educational system toput greater than some value increases, then fromput increases.
7. If educational system toput is nearly minimum, then fromput increases.
8. If educational system toput increases, then filtration decreases to some value and then increases.
9. If educational system toput increases, then regulation less than some value increases.
10. If educational system input decreases, then fromput decreases.
11. If educational system input decreases, then storeput decreases.
12. If educational system input increases, then filtration decreases.
13. If educational system input decreases, then filtration increases.
14. If educational system input is greater than some value, then regulation is greater than some value.
15. If educational system output increases, then fromput increases.

16. If educational system storeput decreases, then feedout decreases.
17. If educational system storeput increases, then adaptiveness increases.
18. If educational system storeput increases, then efficiency decreases.
19. If educational system feedin increases, then fromput increases to some value and then decreases.
20. If educational system feedin increases, then spillage increases.
21. If educational system feedthrough increases, then compatibility increases.
22. If educational system feedthrough is less than some value, then filtration is greater than some value or spillage is greater than some value.
23. If change in educational system feedback is greater than some value, then environmental change increases.
24. If educational system feedback is greater than some value, then storeput is less than some value.
25. If educational system feedback is greater than some value, then regulation is less than some value.
26. If educational system filtration is greater than some value, then compatibility is greater than some value.
27. If educational system is filtration less than some value, then compatibility is less than some value.
28. If educational system filtration increases, then adaptiveness increases.
29. If educational system openness increases, then efficiency decreases.
30. If educational system environmental change increases and fromput increases, then change in feedout is greater than some value.
31. If educational system environmental change increases and fromput increases, then change in feedthrough is greater than some value.
32. If educational system environmental change is greater than some value and feedthrough is greater than some value, then stability is greater than some value.
33. If educational system topout increases and fromput increases, then feedthrough increases.
34. If educational system topout is constant and efficiency is greater than some value, then

regulation is less than some value.

35. If educational system input is constant and fromput is constant, then output is constant.
36. If educational system input increases and storeput is constant, then feedout increases.
37. If educational system input increases and storeput is less than some value, then change in input equals change in storeput.
38. If change in educational system input is greater than change in feedthrough, then spillage increases.
39. If educational system input is greater than some value and spillage is less than some value, then storeput increases.
40. If educational system input is less than some value and spillage is less than some value, then storeput decreases.
41. If educational system input is constant and efficiency at a given time is less than some value, then efficiency increases.
42. If the ratio of maximum educational system selective information to input decreases, then feedout decreases.
43. If educational system fromput increases and output is less than some value, then feedout decreases.
44. If change in educational system fromput is less than some value and change in storeput is less than zero and change in fromput is greater than zero and the negative of change in storeput is greater than some value, then efficiency decreases.
45. If educational system output increases and feedback is greater than some value, then input increases.
46. If educational system storeput increases and (filtration decreases or spillage decreases), then information growth increases.
47. If educational system feedthrough is greater than some value and spillage is less than some value and feedback is greater than some value, then efficiency is greater than some value.
48. If educational system (feedin increases and feedout is constant and compatibility is constant) or (feedin is constant and feedout increases and compatibility is constant) or (feedin is constant and feedout is constant and compatibility decreases), then openness increases.
49. If educational system (feedin decreases and feedout is constant and compatibility is constant) or (feedin is constant and feedout decreases and compatibility is constant) or

(feedin is constant and feedout is constant and compatibility increases), then openness decreases.

50. Change in educational system input is greater than change in fromput.
51. Change in educational system feedin is greater than change in feedout.
52. Educational system efficiency is equal to the maximum efficiency if and only if feedin is equivalent to feedout.
53. If educational system complete connectedness increases, then flexibility increases.
54. If educational system strongness decreases, then wholeness increases.
55. If educational system strongness increases, then hierarchical order decreases.
56. If educational system strongness increases, then flexibility increases.
57. If educational system unilateralness, then hierarchical order.
58. If educational system disconnectedness is greater than some value, then independence increases.
59. If educational system disconnectedness is greater than some value, then segregation increases.
60. If educational system vulnerability increases, then complete connectedness decreases.
61. If educational system passive dependence increases, then centralization increases.
62. If educational system active dependence increases, then centralization decreases.
63. If educational system interdependence increases, then complexity growth increases.
64. If educational system hierarchical order increases, then vulnerability increases and flexibility decreases.
65. If educational system compactness increases, then hierarchical order decreases.
66. If educational system centralization increases, then passive dependence increases.
67. If educational system centralization increases, then active dependence decreases.
68. If educational system centralization is less than some value, then independence increases.
69. If educational system centralization is less than some value, then centralization increases.

70. If educational system wholeness increases and hierarchical order is constant, then integration increases.
71. The limit of the ratio of educational system active dependence to passive dependence as unilateralness increases is equal to one.
72. - 85. *Not applicable here because they deal with specific kinds of school system affect relations (governing, instructional, inquiring, legitimate, referent, reward, etc.)*
86. If educational system state steadiness is greater than some value, then strain increases.
87. If educational system stress is less than some value, then state steadiness is constant.
88. If educational system stress greater than some value increases, then strain increases.
89. Educational system (state steadiness increases if and only if state determination increases) and (state steadiness decreases if and only if state determination decreases).
90. If educational system topout increases, then centralization decreases.
91. If educational system feedin decreases, then unilateralness decreases.
92. If educational system feedin less than some value decreases, then hierarchical order decreases.
93. If educational system feedin decreases, then complexity degeneration increases.
94. If educational system feedout is less than some value, then complexity degeneration increases.
95. If educational system feedthrough increases, then weakness is less than some value.
96. If educational system topout is nearly minimum and fromput increases, then disconnectedness increases.
97. If educational system feedin increases and compatibility is nearly minimum, then disconnectedness increases.
98. If educational system storeput increases and (filtration decreases or spillage decreases), then integration increases.
99. *Not applicable because specific to the referent affect relation.*
100. If educational system complete connectedness increases, then feedin increases.
101. If educational system weakness is greater than some value, then feedthrough is less than some value.

102. If educational system interdependence increases, then feedin increases.
103. If educational system wholeness increases, then regulation is less than some value.
104. If educational system compactness greater than some value increases, then efficiency increases.
105. If educational system centralization increases, then toput decreases.
106. If educational system complete connectedness increases or strongness increases, then toput increases.
107. If educational system complete connectedness increases or strongness increases, then input increases.
108. If educational system complete connectedness increases or strongness increases, then filtration decreases.
109. If educational system complete connectedness increases or strongness increases, then spillage increases.
110. If educational system complete connectedness increases or strongness increases, then openness is less than change in fromput, and change in fromput is less than change in input.
111. If educational system complete connectedness increases or strongness increases, then change in storeput is greater than change in fromput.
112. If educational system strongness increases and hierarchical order is constant, then regulation decreases.
113. If educational system wholeness increases and hierarchical order is constant, then efficiency decreases.
114. If educational system weakness and hierarchical order, then flexibility decreases.
115. If educational system unilateralness, or weakness increases, or disconnectedness increases, then input decreases and fromput decreases.
116. - 136. *are not applicable because they contain specific affect relations.*
137. If educational system feedout is greater than some value and compatibility is less than some value, then segregation is less than some value.
138. If educational system toput increases and compactness greater than some value increases then regulation increases.

139. If educational system topup increases and it is not the case that compactness greater than some value increases, then efficiency decreases.
140. If educational system (fromput is constant or fromput decreases) and complete connectedness increases and strongness increases, then feedthrough decreases.
141. - 142. *are not applicable because they contain specific affect relations.*
143. If educational system feedin is constant then homeostasis is less than some value.
144. If educational system filtration decreases, then isomorphism increases.
145. If educational system filtration is greater than some value, then stability is greater than some value.
146. If educational system adaptiveness is greater than some value, then stability decreases.
147. If educational system topup increases and feedout is nearly minimum, then stress increases.
148. If educational system environmental change is greater than some value, and it is not the case that feedthrough is greater than some value, and feedback is greater than some value, then stability is less than some value.
149. *Not applicable (ibid.)*
150. If educational system automorphism increases, then input increases and storeput increases and fromput decreases and feedout decreases and filtration decreases and spillage decreases and efficiency decreases.
151. If educational system isomorphism increases, fromput decreases and feedout decreases.
152. If educational system state steadiness is greater than some value, then adaptivity is less than some value.
153. If educational system state determination increases, then regulation decreases.
154. If educational system state determination increases, then selective information decreases.
155. If educational system equifinality is greater than some value, then regulation is less than some value.
156. If educational system equifinality at a given time and school homeostasis is greater than some value, then regulation is less than some value.
157. *Not applicable (ibid.)*

158. If educational system toput increases and size is constant, then feedback increases.
159. If educational system environmental change is greater than some value and compatibility is greater than some value and stability is greater than some value, then storeput is greater than some value or filtration is greater than some value or spillage is greater than some value.
160. If educational system toput increases and fromput increases and size is constant, then feedout increases.
161. If educational system output is constant and automorphism decreases and homomorphism is greater than some value, then feedout decreases.
162. If educational system toput is less than some value and feedin increases and stability is less than some value, then stability increases.
163. If educational system toput is greater than some value and feedin decreases and stability is less than some value, then stability increases.
164. If educational system independence increases, then stability is less than some value.
165. If educational system flexibility decreases, then state determination increases.
166. If educational system centralization increases, then state steadiness increases.
167. If educational system complexity greater than some value increases, then size increases.
168. If educational system independence increases and wholeness increases, then state steadiness is greater than some value.
169. If educational system wholeness is greater than some value and centralization is greater than some value, then state determination is greater than some value.
170. - 171. *Not applicable (ibid.)*
172. If educational system automorphism increases, then wholeness decreases.
173. If educational system automorphism increases, then centralization decreases.
174. Change in educational system size is greater than change in hierarchical order.
175. If educational system complexity degeneration increases, then size degeneration increases or disconnectedness increases.
176. If educational system state steadiness is less than some value, then segregation is less than some value and integration is less than some value and homeostasis is less than some value.

177. If educational system weakness is maximum and size increases, then passive dependence increases or active dependence increases.
178. If educational system hierarchical order at a given time is greater than some value and size at a given time is greater than some value, then independence at a later time increases.
179. If educational system size increases and complexity growth is constant, then vulnerability increases.
180. If educational system size increases and complexity growth is constant, then flexibility decreases.
181. If educational system size increases and complexity growth is constant, then centralization decreases.
182. If educational system size is constant and complexity degeneration increases, then disconnectedness increases.
183. If educational system size decreases and complexity degeneration increases, then disconnectedness decreases.
184. If educational system complexity increases and size growth is constant, then compactness decreases.
185. If educational system complexity increases and size growth is constant, then centralization increases.
186. If educational system centralization increases and stress is greater than some value, then stability decreases.
187. If educational system stress is equal to zero and centralization increases, then stability increases.
188. If educational system size increases and complexity growth is constant, then state determination increases.
189. *Not applicable (ibid.)*
190. If educational system homomorphism at time 2 is greater than homomorphism at time 1, then topout is nearly maximum and size degeneration is nearly maximum and complexity degeneration is nearly maximum.
191. If educational system efficiency is greater than some value and compactness is greater than some value, then state determination is greater than some value.
192. If educational system size growth decreases and selective information growth is constant,

then complexity growth increases.

193. If educational system size degeneration decreases and selective information growth is constant, then complexity degeneration increases.
194. If educational system size increases and complexity growth is constant, then *toput* increases.
195. If educational system size increases and complexity growth is constant, then *feedin* decreases.
196. If educational system size increases and complexity growth is constant, then *feedout* increases and change in *feedout* decreases.
197. If educational system size increases and complexity growth is constant, then *feedthrough* increases.
198. If educational system size increases and complexity growth is constant, then *feedback* decreases.
199. If educational system size increases and complexity growth is constant, then *regulation* increases to some value and then decreases.
200. If educational system size increases and complexity growth is constant, then *compatibility* decreases.
201. If educational system size increases and complexity growth is constant, then *efficiency* increases to some value and then decreases.

Verifying the Hypotheses: Relating Theory to Data

An example of an hypothesis which has information theoretic properties:

5. If educational system *toput* increases, then *input* increases to some value and then decreases.

Suppose we were interested in the kinds of students who applied for admission to an educational system (*toput*). Suppose that students are classified according to learning ability by the categories: High, Medium and Low. Suppose at time 1, the distribution of students who applied to the educational system for admission looked like this:

*Observations of **toput** at time 1:*

<u>Student Learning Ability</u>	<u>Frequency</u>	<u>Probability</u>
---------------------------------	------------------	--------------------

c ₁ : High	40	.20
c ₂ : Medium	140	.70
c ₃ : Low	20	.10

An H measure from information theory can describe the uncertainty in this distribution:

$$H = - \sum p(c_i) (\log_2(p(c_i)))$$

Note that $\log_2(p(c_i)) = \ln(p(c_i))/\ln(2)$, where \ln is the natural logarithm.

We can calculate H (uncertainty coefficient) for these three categories:

$$\begin{aligned} H &= - [(.20(\log_2(.20)) + (.70(\log_2(.70)) + (.10(\log_2(.10)))] \\ &= - (.20 (-2.321928)) + (.70 (-0.51457317)) + (.1(-3.321928)) \\ &= - (-0.46438561 + -0.36020122 + - 0.3321928) \\ &= + 1.1567796 \end{aligned}$$

What does this value mean? H is zero when one of the categories has a probability of one, and the remaining categories have probabilities of zero. Uncertainty is maximum when the three categories are equiprobable (if $c_1 = c_2 = c_3 = 0.33333333$, then H is maximum = 1.5849624).

Our obtained value of 1.1567796 is closer to 1.58 than to zero. Thus, uncertainty in the toput distribution is closer to the maximum than to the minimum.

Suppose the educational system can only admit 50 students, who are distributed as follows according to their learning ability:

Observations of input at time 2:

<u>Student Learning Ability</u>	<u>Frequency</u>	<u>Probability</u>
c ₁ : High	20	.40
c ₂ : Medium	25	.50
c ₃ : Low	5	.10

An H measure from information theory can describe the uncertainty in this distribution. We can calculate H (uncertainty coefficient) for these three categories:

$$\begin{aligned} H &= - [(.40(\log_2(.40)) + (.50(\log_2(.50)) + (.10(\log_2(.10)))] \\ &= - (.40 (-1.321928)) + (.50 (-1)) + (.1(-3.321928)) \\ &= - (-0.5877123 + -0.5 + - 0.3321928) \\ &= + 1.4199051 \end{aligned}$$

Notice that the uncertainty is greater in the input distribution than in the toput distribution.

Now, if over time we kept plotting the uncertainty in the topout distribution against the uncertainty in the input distribution, and if we find an inverted U shaped distribution, then this would be evidence to support Hypothesis 5.

The data pair for *H* values of topout and input (1.16, 1.42) would be represented by one of the dots in the scatter diagram. If many paired observations distributions of educational system topout and input were plotted as above according to their respective *H* values, and if the shape of the distribution were in the form of an inverted U, then these data would tend to support Hypothesis 5 in the SIGGS Educational Theory.

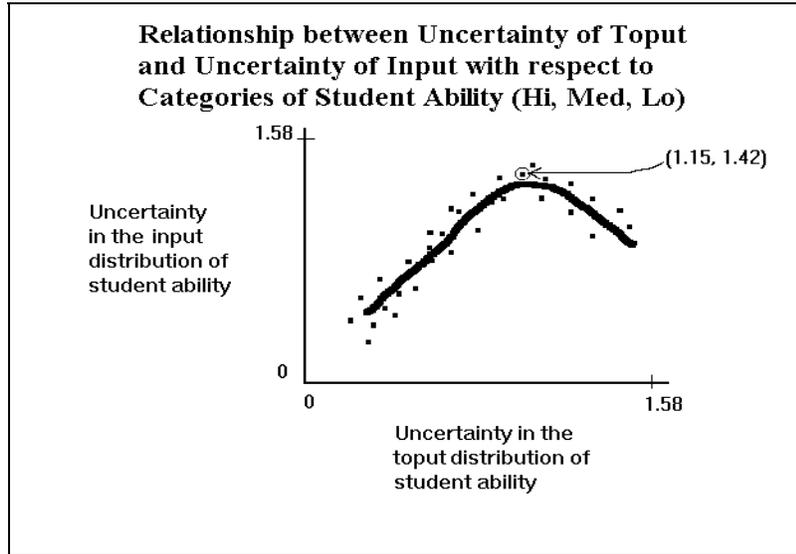


Figure 20. Scatter plot of paired observations of educational system topout and input *H* values for verifying Hypothesis 5.

Note: Need to illustrate other kinds of hypotheses that deal with more complex information functions as well as set and digraph properties.

SIGGS as a Theory Model for Understanding Systemic Change in Education

The Need for Understanding Systemic Change

In the decade following the publication of *A Nation at Risk* in 1983, considerable effort has been undertaken to improve public schooling. Reform efforts have been typically referred to as site-based management, school restructuring, and educational systems design. Researchers such as Banathy (1991), Reigeluth (1992), Frick (1993), and Perelman (1992) have argued for *systemic* change in education. 'Systemic change' contrasts with numerous piecemeal reform efforts which have largely failed in twentieth century schooling.

However, the rhetoric of systemic change is not likely in itself to make any real differences in schooling. Such rhetoric has been around for some time. Understanding of educational systems change is needed for intelligent action.

Changing educational systems, if unguided by adequate *theory* of educational systems

change, will be haphazard at best. The consequences of mistakes can adversely affect the very lives of students, teachers, administrators and their communities. Without an adequate theory of educational systems change, we will continue to restructure education largely by trial-and-error. It is no wonder that educational practitioners often distrust, resist and undermine the efforts of educational reformers. The stakes are very high. The consequences of mistakes can be devastating □ particularly when changing a whole system of education.

Understanding systemic change is not a simple matter. People will need to learn new thinking patterns. Hart (1992) has noted that the vast majority of individual belief patterns do not contain dynamic cycles. Cognitive maps of belief structures tend to be linear with few, if any, feedback loops. Hart indicated that exceptions occurred with those people in professions which taught them to think in dynamic cycles (e.g., ecologists, systems engineers).

Senge (1992) has provided insight into business organizations by identification of about 15 patterns of dynamic cycles. These patterns are not easily described or understood through static print and diagrams. Senge and his colleagues have developed role-playing activities and computer simulations in order to help business people understand these patterns of dynamic relationships □ most of which run counter to individual intuitions about how systems such as business organizations grow and change.

A Theory for Understanding Educational Change

Maccia and Maccia (1966) have developed an educational theory which is based on the SIGGS Theory Model. SIGGS in turn was created from concepts and principles in set, information, di-graph and general systems theory. Maccia and Maccia's educational theory contains 201 hypotheses, some of which have been verified through extant practice. For example, one of the hypotheses is: *If centralization in an educational system increases, then active dependence decreases.* Centralization is concentration of channels within a system. Active dependence is components which have channels from them. One only need look at the many instances of this pattern in the past 50 years. In the school consolidation movement during the middle part of this century, many American school systems increased in size and became highly centralized with respect to administrative decision making. The voices of concerned teachers, students, and parents and community members currently seem to have had little impact on administrative decision making. Most school systems operate largely as they have in the past, despite many well-intentioned reform efforts.

Further evidence to support this hypothesis comes from recent reform efforts in the Chicago Public Schools (*Closer Look*, 1994). The city-wide public school system was divided into individual and relatively autonomous local school systems. Key decisions are now made by Local School Councils, teachers and principals. Centralization has decreased, and it would appear that more parents, teachers and local community members are having their voices heard by the Local School Councils (*Closer Look*, 1994).

Maccia and Maccia's educational theory consists of 200 hypotheses in addition to the one illustrated above. To understand many of these hypotheses it is necessary to know the concepts and principles in the SIGGS Theory Model. (See above definitions of SIGGS concepts):

Basic SIGGS Properties: component, affect relation, information, selective information, system, negasystem, toput (system environment), input, storeput, fromput (negasystem environment), and output. (See Figures 4 and 6).

SIGGS Structural Properties (system configuration): system complete connectivity, strongness, unilateralness, weakness, disconnectivity, vulnerability, passive dependence, active dependence, segregation, interdependence, wholeness, integration, hierarchical order, flexibility, homomorphism, isomorphism, automorphism, compactness, centralization, size, and complexity.

In addition to system configuration properties □ i.e., how components are connected or related to each other □ there are dynamic properties which characterize how systems change through time.

SIGGS Dynamic Properties (system temporal change): system environmental change, feedin, feedout, feedback, feedthrough, filtration, spillage, regulation, compatibility, openness, adaptivity, efficiency, size growth, complexity growth, selective information growth, size degeneration, complexity degeneration, selective information degeneration, stability, state steadiness, state determination, equifinality, homeostasis, stress, and strain.

'Filtration' is defined as restriction in educational system toput, i.e., a restriction in the choice environment. See Figure 7. A typical example is that state textbook adoption agencies restrict the availability of textbooks from which local schools can choose. Furthermore, state adoption committees in Texas, California, and New York act as significant filters of textbooks published in general. One of the Maccia and Maccia hypotheses is that as filtration increases, then educational system input decreases. Decreased input with respect to variety and richness of curriculum resources implies selective information degeneration in educational systems.

Understanding the Present and Past: Making the Familiar Strange

The SIGGS system properties, both structural and dynamic, can provide us with concepts and principles in order to understand existing educational systems in new ways. For example, I have known for some time about the power and influence that the textbook adoption committees in Texas, New York and California have had on the textbook publishing industry. It did not occur to me that this was an example of filtration until I tried to generate examples of this negasystem property.

The hypothesis that: "If filtration increases, then uncertainty in system input categories decreases" got me to thinking further. Input is 'selective information' in a system. 'Information' in the SIGGS theory is a characterization of occurrences through use of categories in a classification (a technical meaning from information theory). 'Selective information' means that there is uncertainty in the distribution of alternative categories. For example, if there are only two kinds of textbooks taken in by a system (such as math and history), and the probability of observing a math book is .90, versus .10 for a history book, then there is little uncertainty in the

classification of textbooks. On the other hand, if the probability of a math book being observed is .50 and likewise for a history book, then uncertainty is maximum (for when there are two alternatives). An H measure from information theory can be used to indicate the uncertainty in a probability distribution of discrete alternatives.

When the uncertainty of occurrences of types of input increases, this means that there are more alternatives in the distribution of inputs; and the probability of occurrence of any one category of input is relatively small (hence greater choice within the system). When the uncertainty of input categories decreases, there is less choice within the system (fewer alternatives as a small number of categories have relatively high probabilities). If we look at categories of curriculum content selected by public educational systems, they are relatively few in number and fall into traditional subject matter domains such as history, mathematics, science, language arts, etc. Moreover, that content is represented largely in abstract form (printed text), with some static pictures □ i.e., in textbooks.

As a further example, if we go to an ice cream store, and our only choice is chocolate, then there is no uncertainty in the flavor of ice cream we might eat (that which becomes input in our digestive system). If our choices are vanilla, chocolate and strawberry, then there is greater uncertainty as to which ice cream flavor that we as a customer might choose to eat. If there are 33 flavors, uncertainty in the input distribution is likely to be even greater.

Most public school classrooms have struck me as rather barren places for learning to occur. Why is that? Basically, the choices that students have with respect to curriculum content are largely limited to a few textbooks and what a teacher says and does. Is this an example of selective information degeneration, a consequence of decreased input in an educational system that is predicted by the SIGGS theory? Compare this to the content outside of school classrooms and buildings as sources of potential learning "materials." The backyard behind my house and the city courthouse are much richer content resources, for example, for learning something about biology and the criminal justice system, respectively.

These thoughts lead me to wonder what would happen if current policies regarding textbook adoption at local, state and national levels were removed. With less filtering of content, there should be a greater variety of curriculum made available for educational systems to choose from. With more choices available to an educational system, we would expect to find a greater variety of curriculum resources taken in by that system. Hence, students in that system would have greater choice in curriculum resources to facilitate learning.

I did not have these thoughts until I had begun to consider properties of systems in general, and their relationships as hypothesized in the SIGGS educational theory. I believe that my understanding of educational systems concepts and relationships gives me new lenses □ new ways of seeing educational systems □ that I did not have before.

Inventing the Future: Making the Strange Familiar

It is difficult for us to envision new educational systems. Once we understand educational systems in new ways, we can "break set" in how we think about education. In the U.S. we

typically think of an educational system as a school district consisting of a number of school buildings with classrooms, people licensed as teachers, students organized into groups largely by age, principals, a superintendent and a school board. It is hard for us to think about education differently.

Let me illustrate with some of my thinking when starting from a "clean slate" in considering education and educational systems. In the SIGGS theory a 'system' is defined a group of components with at least one affect relation which has selective information. The basic types of components in any educational system are teachers, students, content and contexts (Steiner, 1988). Instead of focussing on the components *per se*, I have recently found it more enlightening to focus on their interrelationships (affect relations □ cf. Frick, 1991; 1993). The basic classes of affect relations in any educational system are teacher-student, teacher-content, teacher-context, student-content, student-context, and content-context relationships.

A *teacher* is one who guides the learning of another. This defines a kind of affect relation between two persons. Person A may guide the learning of Person B, and Person B may guide the learning of Person A. For example my wife of Irish descent has taught me to cook Chinese style dinners. I have given her guidance in using our computer at home. Furthermore, guidance of learning is not restricted to direct instruction (e.g., lecture, demonstrate, answer questions, ask questions). Learning may be guided indirectly as it is frequently in Montessori classrooms in which it occurs through interaction with the curriculum materials. Furthermore, the older students may guide younger students in Montessori classrooms in which mixed-age groups exist. These older peers act in the role of teacher (i.e., one who guides the learning of another).

If teaching is viewed as an affect relation, then it unbinds us from thinking of teacher as a component in education. *Teaching is a relationship between two persons, one of whom guides the other who follows.* 'Teaching relationships' can exist among lots of pairs of persons. Such relationships are not limited to those persons in schools with licenses to guide the learning of students.

A *student* is one who intends to learn through guidance from a teacher. In contrast, a learner is one who attempts to learn without guidance □ e.g., by trial-and-error. An undesirable kind of affect relation would be one who is being forced to learn against his or her will. When students are forced to attend school and required to learn subjects that do not interest them, this is not a good kind of teaching-studenting affect relation. The most desirable kind of teaching-studenting affect relation is one in which one person intentionally guides another who wants to learn.

Content is that which is to be learned. There are both student-content and teacher-content affect relations. The kinds of student-content affect relations that we ought to create in education are cognitive, conative and affective. We want students to come to know the objects of learning (cognitive relationship with subject matter), to value such objects (conative), and to associate positive feelings with the objects of learning (affective). Subject matter need not be constrained to extant classifications such as mathematics, science, history, language arts, etc. The types of teacher-content affect relations can be similarly classified. Teachers should know the subject matter (and how to guide learning of subject matter, which is a further kind of understanding of content), value it, and love it.

Context is the setting in which guidance of learning occurs. When my wife helps me learn to cook, the context we work in is the kitchen. When I help her to use our computer, that usually occurs in the context of our home office area. Typical contexts of present-day, formal educational systems include classrooms in school buildings, principals, janitors, local school boards, furniture, black/white boards, overhead projectors, computers, books, libraries, gymnasiums, school buses, cash, cafeterias, food, etc. Context could also include state departments of education, and national departments of education □ if these are considered to be part of the education system.

We have student-context, teacher-context, and content-context affect relations. When I am learning to cook, student-context relations include my reading a recipe from a book, chopping vegetables, measuring rice and water, etc. When my wife is learning to use a word-processor to make large-print labels, student-context relations include her using a computer system and software program. (She makes curriculum materials for her pre-school Montessori classroom, which is a teacher-content relation.) There are also content-context affect relations. The object of learning may be symbolically represented through printed words in a book (e.g., a math textbook); the object of learning might be iconically represented through images on a videotape (e.g., a documentary on Martin Luther King); the object of learning might be physically present in the current setting (e.g., artifacts from an archeological dig; the city mayor herself).

Continuation of Simulosophy in the Future

If we are successful in the near future, we will have laid the groundwork for SimEd. Such a simulation will require a set of underlying rules or principles of system change under various conditions. If these rules are not valid, then the systems simulation might be interesting but misleading. Thus, we need to validate the rules with empirical evidence wherever we can find it in extant research.

In the spring semester, 1995, Ted Frick is leading a doctoral seminar (R695) at Indiana University in which the work in this Asilomar Conversation will be continued.² We will start with an existing theory of education developed by Maccia and Maccia which contains 201 hypotheses concerning relationships among properties of educational systems. To understand their theory, we will need to reach mutual understanding of about 60 properties of systems in general. Some of these properties characterize system configurations (e.g., complete connectedness, vulnerability, size, complexity, wholeness) and some characterize system temporal dynamics (e.g., filtration, feedout, feedback, regulation, adaptivity, compatibility, homeostasis, stress). We will be expanding upon my manuscript in progress, aimed at furthering the understanding of the Maccia and Maccia theory.

²Paul, Kayla and Andy plan to keep in touch through the Internet and the World-Wide Web during the seminar.

We will most likely be revising this theory as we accumulate evidence. The revised theory will be the initial set of rules for the expert system that is the kernel for SimEd. Also, as we accumulate examples from past and present research, these may serve □ with some creative modification □ as potential scenarios for SimEd.

The primary reason that this theory has received little attention during the past 30 years is that it requires a paradigm shift in people's thinking patterns (cf., Thomas Kuhn (1970), *The Structure of Scientific Revolutions*). Systemic thinking is rare (Hart, 1992). Systemic thinking may even require a different kind of intelligence that is not fostered by existing cultures and educational systems. See for example, Howard Gardner's (1985), *Frames of Mind: The Theory of Multiple Intelligences*. Systemic thinking may be a further stage of cognitive development that goes beyond Jean Piaget's original stages of intellectual operations (cf. Senge, 1990; Campbell, 1976).

Working together, we expect to create a manuscript which can help others to understand these systems properties and, in turn, to understand the hypotheses of the educational systems theory. We expect our efforts in R695 to result in jointly authored publications such as a book, a series of articles, and/or hypermedia documents on the World-Wide Web. In summary, we expect that the major outcomes in this course will be for each participant to make a significant contribution to this cooperative research endeavor □ the ultimate goal of which is to create a major paradigm shift in how people think about education.

This is undoubtedly an ambitious undertaking. But it should be exciting, and we simulosophers, of course, believe that it is very worthwhile. We plan to continue this conversation theme during the 1995 Asilomar Conversation. Based on the progress of the R695 seminar, we might even have a rudimentary version of the simulation to play with during that conversation.

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