Structures and Systems

Joan B. Stone
Rochester Institute of Technology

Instructional systems have become prevalent both as organizational devices and as descriptive tools for educational process. As an organizational device, a system has the advantage of simplicity. The learner begins as raw material, proceeds through the system, loops back when necessary, and comes out the end possessing pre-determined knowledge. Instructional systems are the epitome of the Tyler rationale (1949). Although much of what I want to say about systems has already been said elsewhere, I believe it has usually been said to sympathetic audiences. Educators hesitate to communicate across party lines. Instructional technologists and curriculum theorists seldom confront one another. I am both a faculty member of an institute of technology and a student of educational process. Instruction, for me, is a process of inquiry, involving the interaction of student, teacher, content, and setting. My purpose in this paper is to show how the technological or systems model obscures instructional inquiry and to suggest structuralism as an alternative methodology for the study of instructional process.

Although *structure* may initially seem more static, it may be a better word to describe the relation between knower and known. Consider a bridge. While it appears relatively stationary, it must assimilate the vehicles passing over it as individual cables, each in turn, accommodate the added weight. In fact, the bridge is a very dynamic object able to accommodate a variety of environmental impacts. It is probably obvious from this metaphor that structure is being used in the Piagetian sense. Piaget defines a structure as a set of transformations having certain properties. For example, these transformations have self-regulatory mechanisms which in effect keep the bridge from galloping.[1] The transformations are in one sense or another, reversible. As a result, structures can include dialectical process as well as the implicational arrows of a system. This paper suggests that instructional structures, based on the assumption that knowledge is constructed not copied, are more appropriate models for educational process than the more common instructional system.

It might be argued that I am making a false distinction between structures and systems; that really systems theory is the American version of European structuralism. Piaget and others have suggested that this is the case and it may be true in the social sciences. I do not believe it is true in educational practice. I question the use of systems concepts to describe, explain, or facilitate instruction. To illustrate this I will first briefly explain what I understand instructional systems to be, what the underlying assumptions appear to be, and finally, what are the limitations of systems.

Description

Hussain describes a system as an assemblage of components forming a whole which has been designed for an objective and organized according to a plan (1973, p. 60). One characteristic of an instructional system is that objectives are always clearly stated in measurable terms. Another characteristic is the notion of components. In instructional systems there are input and process components. Input components are usually people and things; that is, teachers, learners, their characteristics, books, media, etc. Process components are actions; that is, analysis, inventory, assessment, identification, design, distribution, scheduling, evaluation. All of these people, things, and actions combine to form a self-regulating whole, the output of which is hopefully a learner who has successfully met the system's objectives.

Let's look at a particular learner who meets such a system. Much has been done before this learner has arrived on the scene. His teachers know what to expect from a typical learner of his age and ability, so they have eliminated much instructional content which would be too easy or too difficult. External constraints have limited the number and kinds of resources available to the learner. Most importantly, the objectives which he must meet have been determined and written clearly so he can understand exactly what he must do. The first thing he encounters is a pre-test. Maybe he already met the objectives and a good system is designed to determine this fact. The pre-test helps both learner and teacher identify those objectives which the learner must attain. Once this identification has occurred, the teacher or systems manager decides which learning tasks will most likely help the learner meet the objectives. The learner then proceeds through the set of tasks, working at his own pace within the limits of environmental constraints. To determine if the learning tasks have actually helped the learner meet the objectives, a post-test is given. The teacher and learner evaluate the learner's performance on the post-test. If the learner is successful, this particular instructional system is finished. If not, the learner is looped back through the system using the same or alternate learning tasks. This looping continues until the learner has successfully met the objectives.

Assumptions

If the above brief sketch is a reasonable description of instructional systems as they commonly occur in practice, then we can look at certain assumptions which seem to form the basis for this concept. First is the assumption that objectives can be pre-determined for a particular learner. We must assume that the objectives written by the instructor are shared by the learner. Since we know that this is often not the case, instructional systems include the notion of learner management. Learner management includes motivating the learner to want to meet the pre-determined objectives. The systems manager is not concerned particularly with why the learner might want to meet these objectives, but only that he does have this desire. Doyle (1977) suggests that a possible reason for accepting pre-determined objectives is to receive a grade. In effect, the learner becomes willing to exchange performance for grades.

Another assumption which underlies an instructional system is that knowledge is a copy of reality which can be passed from one person to another like a commodity. The learner who progresses through the system becomes like a product which acquires certain characteristics as it is passed through a machine. If one set of learning tasks does not produce the desired result, another set is substituted until a suitable finished product results.

The above assumption stems from a third which views education as an empirical-analytic science. The learner's performance becomes the dependent variable. All other components of the system are independent variables which can be systematically manipulated. Failure to produce a desired result is explained in terms of incorrect combinations of independent variables. Much educational research is devoted to finding the proper combination of learner aptitude and instructional treatment variables to ensure a particular learner performance. A system then is based on causality, that event A will lead to event B. The arrows connecting the boxes in a schematic drawing of a system represent implicational statements.

Limitations

Given the above description and set of assumptions, I believe that there are several limitations inherent in the use of systems concepts to describe, explain, or facilitate instruction. The first limitation is related to the assumption the systems objectives can be pre-determined and that proper management will ensure that the learner shares these objectives. It seems to me that there must be a discrepancy between the naive learner's understanding of a particular objective and the teacher's understanding of that objective. Each is looking at the objective from a different point of view. For one it is an endpoint. For the other it is one part of a larger conceptual scheme. Since this scheme is by definition unknown to the learner, or else he would not be a learner, the objective cannot possibly have the same meaning for him and his teacher. Thus, we find students who carefully attempt to achieve discrete objectives and who totally miss the implicit connections between them. The system easily overlooks learners who have demonstrated the required performance, but who have not shared at all the intentions of the teacher who wrote the objectives. In designing an instructional system, the teacher begins with an overall system purpose. This purpose is derived from experience and consequently is not accessible to the learner at the time he encounters the system.

In practice, instructional systems seem limited to a behavioristic theory of knowledge as a commodity. Knowledge is apparently viewed as something which can be passed from teacher to learner through repeition, feedback, and reinforcement. According to von Glaserfeld such a theory has *"on one side, an existing, fully structured World and, on the other, a Knower whose external task is to* get to know *that world" (1977, p. 4).* It would follow then that we have acquired knowledge of an object in the world when our internal representation of that object matches reality. But this leads to an inescapable dilemma.

> *It is impossible to compare our image of reality with a reality outside. It is impossible, because in order to check whether our representation is a "true" picture of reality we should have to have access not only to our representation but also to that outside reality* before *we get to know it. And since the only way in which we are supposed to get at reality is precisely the way we would like to check and verify, there is no possible escape from the dilemma (1977, p. 6).*

It seems that the setting down of objectives leads us directly into von Glaserfeld's dilemma. The objectives become external reality, against which a learner measures his own performance. There are problems both for the learner who is wrong and the one who is apparently right. In order to know he is wrong, he must first know what it is to be right. But this implies that he has access to this external reality before he gets to know it. This learner asks the question, *"Why am I wrong? I don't understand why my performance is incorrect."*

The other set of learners have a different problem. Their performance apparently "matches" the external reality, but their question is, *"Why are we right?"* Unfortunately, too few ask this question, but simply check off this objective as accomplished. This limitation is not necessarily inherent in instructional systems. It is a limitation of systems designers who hold the philosophical view of knowledge as copy. The organizational simplicity and elegance of an instructional system often lead us to be satisfied with less than we had intended. Both teacher and learner feel good when a long list of objectives has been checked off. It then becomes difficult to question whether or not knowledge has actually been constructed.

If instructional process could be completely described in hypothetical-deductive terms, then some of the above limitations might be considered merely practical problems whose solutions could be attained with a little effort. But if instructional process cannot be adequately represented in these terms, the limitations become theoretical problems.

Bernstein (1976) suggests that inquiry about the nature of social process has three "moments."

> *The search for empirical correlations, the task of interpreting social and political reality, and the critique of this "reality," are not three distinct types of inquiry. They are three internal moments of theorizing about social and political life (p. 174).*

If we can assume that instruction is a form of social process and if we limit ourselves to systems concepts as I have described them, then we acknowledge only the first of Bernstein's three moments. All teachers, not only educational researchers, are involved in a process of inquiry on some level. We may not be concerned with generalizations about all students; but if we are teaching, we must be asking questions about particular learners. We must acknowledge those aspects of instructional process which cannot be described in empirical-analytic or hypothetical-deductive terms. Systems concepts may have originally had the potential for this. In practice, instructional systems do not achieve this potential.

An Alternative

Since the 1960's, science and mathematics education journals especially have been filled with educational applications of Piaget's theory of intellectual development. Although the content of Piaget's work is undeniably interesting, it may turn out that his method of inquiry will ultimately have a greater influence on education. At this point, I will try to explain Piaget's version of structuralism as a research methodology and then try to show how it might be used to better describe and explain instructional process.

Definition

A structure is a self-regulating set of transformations. There are three important ideas in this definition. Most important is that structures consist of transformations, not static forms. A structuralist is interested, not only in describing forms, but in explaining changes in forms. For example, the mathematical structuralist studies, not particular numbers, but a set of transformations of those numbers and the relationship between those transformations. The fact that a structure is a *set* of transformations is also important. By definition, a set has certain laws or properties which connect its elements with one another. This means that a given structure will maintain its own laws and properties even as it becomes part of some larger structure. For example, the rational numbers form a set which has certain properties. These properties are unchanged even when the rational numbers are considered a subset of the real numbers or the complex numbers. Finally, the third important idea in the definition of structure is self-regulation. Because structures are sets of transformations, they would easily "come apart" without a self-regulating mechanism. This mechanism varies according to the kind of structure. Mathematical structures, such as groups, are self-regulating because each transformation has an inverse. Biological structures are self-regulating through rhythmic mechanisms. Social and psychological structures depend on a process of anticipation and feedback for self-regulation (Piaget, 1971, p. 3-16).

Assumptions

Piaget's concept of structuralism is based on certain assumptions about knowledge. The most important of these assumptions is that knowledge is constructed, not copied. A key idea in all of Piaget's work is the process of reflective abstraction. Piaget believes that we construct knowledge by reflecting on our own actions, where actions may be either physical acts or thoughts.

> *"Reflective abstraction" ... does not derive properties from* things *but from our ways of* acting on things, *the operations we perform on them; ... from the various fundamental ways of* coordinating *such acts or operations (1971, p. 19).*

The search for strcuctures is a limitless process where any given structure becomes an element of another "larger" structure.

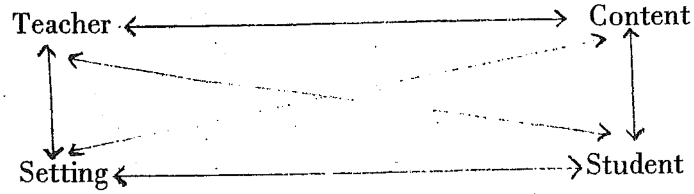
> *Any content is form relative to some inferior content and any form the content for some higher form (1971, p. 140).*

For Piaget, structuralism is a method, not a philosophy or a doctrine. It is a method which

> *does not suppress...other dimensions of investigation. Quite the contrary, it tends to integrate them, and does so in the way in which all integration in scientific thought comes about, by making for reciprocity and integration (1971, p. 137).*

Possibilities

Because structuralism is concerned with transformations, it holds possibilities as a method for the study of instructional process. For example, the following scheme suggests several transformations which taken together make an instructional structure.



This scheme is not intended to represent connections between independent and dependent variables. It is intended to demonstrate possible transformations of given elements in instructional process. Thus, any one element has the potential of being transformed into any one or all of the other elements. A student can at once become teacher, content, or setting. A study of these potential transformations is instructional inquiry. What does it mean for student to become teacher or teacher to become student? How does content change to setting or vice versa? I have no answers to these questions. My own teaching and research are only beginning to fall within this framework.

I am currently teaching geometry to engineering student at the National Technical Institute for the Deaf. While I am a teacher in this role, I am simultaneously a researcher studying instructional process. We write our own text as the course develops. Following each class, I write my perceptions of our interactions. These notes are duplicated and shared with my students. Initially, I did this because I had no time to search for a suitable text for deaf students. I have come to realize that I never will find a suitable text. Each group has its own text. One cannot be adapted for use with a second group.

What exactly is this "text"? So far, it has been my reflections on my own actions as I interact with my students. It is a form of reflective abstraction which probably reads to an outsider like any other geometry text. It isn't. It is a particular text, stemming from the interaction of geometry content with my actions, the actions of my students, and the particular setting in which we find ourselves. At this point it is only half a text because it is only my reflections. The complete text would have to include my students' reflections as well.[2] In a sense, they have such a record, more or less complete, in the problems they have attempted to solve. But this is not an explicit reflection on their actions (with the possible exception of one student whose work included a discussion of what he was doing) and I have never responded directly to their work. Because I am actively involved in this process of reflective abstraction, I am both teacher and learner in my own class. While these texts served initially to give form to the content of our interaction, they are now available to me as content from which I can perhaps begin to extract the form of instructional process.

It is obvious from this brief description that I have gone only a short way down the road of structuralist inquiry. In effect, I have only a description of the teacher to student transformation. The other possible transformations, e.g. student $\longleftrightarrow$ content, content $\longleftrightarrow$ setting, student $\longleftrightarrow$ setting, etc., are left to be described. Once these transformations are made explicit, there are still the questions of what laws connect them together and what are the self-regulatory mechanisms which keep an instructional structure from "coming apart."

The laws which connect the transformations in a structure and the self-regulatory mechanism of that structure are related to each other through the notion of invariance. If, for example, we consider a set of transformations in space defined on geometric figures which holds invariant the distance between any two points, we have the structure of Euclidean geometry. If we hold the relation of betweeness invariant; that is, if point B is between point A and point C, then any transformation must preserve this relation; we get the structure of projective geometry. Finally, if we define a set of transformations on geometric figures such that the openess or closedness of those figures is preserved, we have topology. The above description is an over-simplified portrayal of Klein's (1939) Erlanger program, but it serves to illustrate an important connection between systems and structures. That is, if we assume that purpose is shared by all elements of an instructional structure and if we hold that purpose invariant, then a structure has all the properties of a system. The difference is in the theorist's point of view. It is similar to the difference between traditional Euclidean geometry and transformational Euclidean geometry. In the first case, the focus is on an aximatic exposition of the relations between geometric elements. In the second case, the focus is on particular kinds of transformations; i.e., movements in space of geometric elements. Axioms are not ignored, but there is an extension beyond the axiomatic development to the relations between the transformations themselves. For example, the set of distance preserving transformations form a group. In other words, the relations between the transformations have certain properties themselves. In a sense, transformational geometry allows for a higher form of abstraction where previous form becomes the content of new forms.

Many of us would not want to extend the geometric metaphor any further. We want to hold invariant the purpose, however general, of an instructional structure. If we do this, we have lost nothing from the system point of view, but we have extended this view to a study of the transformations within an instructional system. It then becomes possible to study the system purpose and objectives, not as givens, but as derived from the interactions of student, teacher, content, and setting.

Suppose that we assume the purpose of instructional structures can vary. What effect does this have on our inquiry? In geometry, when we no longer held distance invariant, the result was an equally rigorous structure; that is, projective geometry. By assuming that purpose can vary, we are not saying there is no purpose. Rather, purpose is situational and transient. We could also explore the possibility that nothing is invariant, in which case we enter the realm of structureless structures. In any event, I would argue that structuralism, as a method of inquiry, is every bit as rigorous as hypothetico-deductive research and that it can serve to focus on aspects of instruction that would otherwise be obscured.

FOOTNOTES

1. The "galloping bridge" is a reference to the Tacoma Narrows Bridge at Puget Sound, Washington. In 1940, four months after the bridge was completed and open to traffic, *"a mild gale set the bridge oscillating until the main span broke up, ripping loose from the cables and crashing into the water below. The steady wind produced a fluctuating resultant force in resonance with a natural frequency of the structure. This caused a steady increase in amplitude until the bridge was destroyed."* A similar situation can occur when a column of soldiers marches in step across a bridge. The movement of the column can set the bridge *"vibrating with a destructively large amplitude if the frequency of their steps happens to be some natural frequency of the bridge. This is the reason why soldiers break step when crossing a bridge."*

Resnick, Robert and David Halliday. PHYSICS FOR STUDENTS OF SCIENCE AND ENGINEERING. New York: John Wiley & Sons, Inc., 1962, pp. 312-313.

2. To construct a complete text would require work similar to that of Madeleine Grumet in which the student reflects on his experience of an educational event and the teacher responds to the student's account of his experience. See especially, "Supervision and Situation" in THE JOURNAL OF CURRICULUM THEORIZING, 1:1.

REFERENCES

Bernstein, Richard. THE RESTRUCTURING OF SOCIAL AND POLITICAL THEORY. New York: Harcourt, Brace, Jovanovich, 1976.

Doyle, Walter. Paradigms for research on teacher effectiveness, in L.S. Shulman (Ed.) REVIEW OF RESEARCH IN EDUCATION. Volume 5. Itasca, Illinois: F.E. Peacock, 1977.

Hussain, Khateeb. DEVELOPMENT OF INFORMATION SYSTEMS FOR EDUCATION. Englewood Cliffs: Prentice-Hall, Inc., 1973.

Klein, Felix. ELEMENTARY MATHEMATICS FROM AN ADVANCED STANDPOINT. New York: The Macmillan Company, 1939.

Piaget, Jean. STRUCTURALISM. New York: Harper & Row, Publishers, 1971.

Tyler, Ralph. BASIC PRINCIPLES OF CURRICULUM AND INSTRUCTION. Chicago: University of Chicago Press, 1949.

von Glaserfeld, Ernst. THE CONCEPTS OF ADAPTATION AND VIABILITY IN A RADICAL CONSTRUCTIVIST THEORY OF KNOWLEDGE. Paper presented at the 7th Annual Meeting of the Jean Piaget Society, Philadelphia, May 1977.