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Instructional Logistics and Chunque-Based Learning Systems

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INSTRUCTIONAL LOGISTICS AND CHUNQUE-BASED LEARNING SYSTEMS

by

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To my wife Donna and her mother Marie.

Without their support this book would not exist.

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Ian A. McArthur

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ABSTRACT

Instructional Logistics and Chunque-Based

Learning Systems

by

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Existing instructional design and curriculum design strategy components were synthesized to provide a comprehensive set of design models for the development of learning systems. The term instructional logistics was coined to define the management of student progress through a series of customized learning experiences. Strategies were developed for the design of student-centered learning systems by partitioning a curriculum into meaningful and manageable pieces (called chunques) and by manipulating those pieces to create personalized and individualized paths through a series of self-contained learning experiences. Strategies were developed to organize a collection of chunques into a path based on initial simplified mental models designed specifically to make the subject matter more appropriate for novice learners. Two types of paths were proposed: paths created prior to instruction based on the best guess at what is optimal for the particular circumstances (anticipatory paths) and paths modified on the fly based on diagnostic information gathered during the learning process (adaptive paths).

Curriculum design decisions were based on two propositions: that curriculum decisions can be categorized as value-laden decisions, based on some conception of worth, or as technical decisions, based on instructional needs. The three souls proposition was developed, which proposes that educational goals can be categorized as education-to-be, sagacity-to-know, or training-to-do.

(254 pages)

INTRODUCTION

There is a need in instructional technology to systematically review, synthesize, integrate, and extend a substantial body of recent research and theoretical knowledge. This body of knowledge, which is comprised of fragmented pieces from many domains both within and outside of the traditional realm of educational technology and instructional design, has been incorporated piecemeal into what has become a fragmented collection of diverse models. Snelbecker (1985) recognizes a continuing need to incorporate these many diverse notions into integrated theories. Reigeluth (1983a) has stressed the need within the domain of instructional design for integrative theoretical work to bring these new notions together into comprehensive prescriptive theories and models.

One problem is to develop more global models that will comprise a unified set of theoretical principles, models, and guidelines that bear on the design of student-centered learning systems (Merrill, 1989). A particular area of concern identified by Merrill is a need to develop prescriptions for macro-level course organization and the management of learning experiences. This paper presents one approach to address this problem.

One purpose of the investigations that comprise this work was to provide a knowledge base that integrates existing principles and prescriptions for the management of learning experiences. Another purpose was to explore and include notions in the literature not previously addressed in a systematic manner. The product is a book describing a modular and comprehensive set of propositions, principles, and guidelines for the design of chunque-based learning systems focused principally on the management of student progress through an ordered collection of learning experiences.

The initial impetus for this work was the call by Reigeluth (1983a) for more attention to integrative theory. There is a clear need for efforts to gather together and synthesize a substantial body of existing knowledge to develop a unified theory for the management of learning experiences. In this context, the phrase "management of learning experiences" incorporates more extensive questions than those originally suggested by Merrill (1989) in his call for prescriptions relating to course organization. In addition to organizing a course there is a need to develop a scheme for managing the progress of a student through the learning experiences which are developed to present the course (or program) to the learner. Initial reflection on the need for a new unit of analysis that is larger than the "single idea" of the original component display theory has uncovered a need to meld value-laden curricular decisions with more technically-oriented instructional decisions. This initial work has developed into the foundation of a systematic way of designing learning systems based on the identification and manipulation of the smallest meaningful pieces of content in the curriculum. These pieces, based on the notion of mental models and called *chunques*, are minimal units of content (or clusters of related ideas) that have meaning in their own right to learners. It may be profitable to synthesize a number of existing and newly developed propositions in a way that will coalesce into what is tentatively called "chunque-based learning systems."

The goal is to re-educate the perceptions:

> To reframe the issue of the contributions of research to policy and practice, suggesting that the contribution lies not so much in immediate and specific applications but rather in constructing, challenging, or changing the way policymakers and practitioners think about problems. (Shavelson, 1988, p. 4)

The particular purpose of this study was to refine these developing notions into a more robust set of prescriptions, models, and theoretical propositions.

Specific Objectives

1. To extend the existing knowledge base to include notions from areas of research outside the traditional realm of instructional technology.

2. To develop definitions and clarification of concepts and principles related to the management of instruction and the development of learning systems.

3. To provide an explanation of relationships between these concepts and principles.

4. To provide a synthesis of existing, usually disparate, theoretical notions that pertain to the management of instruction and the development of learning systems based on chunques, in which the primacy of student needs is fundamental.

5. To formulate a unifying framework that will encourage the incorporation of new and more appropriate models as they are developed: a modular plug-in design, so to speak.

REVIEW OF LITERATURE

In his 1988 presidential address to the American Educational Research Association, Richard Shavelson presented the view that a primary function of educational research is to provide a knowledge base that educational leaders can use to inform their decisions. Shavelson (1988) suggests that this knowledge base should be one of many factors that collectively reform the mind frame of educational decision makers and practitioners. He believes that the link between research and practice is through knowledge that, "provides evidence that may confirm, construct, challenge, or change teacher's mindframes" (p. 10). Elliot Eisner (1985) expresses this shift in mindset as re-educating the perceptions.

Snelbecker, in discussing the need for theory in psychology and education, states, "The need for theory in both disciplines is great not only to provide organization for our accumulating, and somewhat scattered, facts and principles, but also to provide a more systematic basis for dealing with practical problems" (1985, p. 44).

Within the field of instructional design, Reigeluth (1983a) expresses a need for more integrative theory building to develop a common body of understanding and a common vocabulary across the domain. He suggests that, while there is a constantly expanding collection of prescriptive models, they tend to address isolated instructional problems. Reigeluth urges that more effort be focussed on the challenge of developing unified sets of design models and prescriptive theories.

Merrill, Li, and Jones (1990) reinforce this view. In explaining the shortcomings of first-generation instructional design, they suggest that more global models are needed as well as a different and larger unit of analysis. They identify as one of the shortcomings with current investigations the micro focus on small pieces of content and prescriptions for teaching them.

The problem is not so much what to do but to know when to do it (Gagne, 1987; Shavelson, 1988) and to insure that it is done (Gropper, 1983a, 1983b). While we have many pieces of the instructional puzzle, we lack understanding in two important areas: We lack prescriptions for the design and development of integrated environments for learning and we lack prescriptions for the management of students through such systems.

In particular, Merrill (1989) identifies the lack of prescriptions for course organization. In his keynote address to the Association for Media and Technology in Canada, he stated, "We have no prescriptions for course organization . . . what are the rules . . . what are the prescriptions . . . we must systematize the underlying principles."

There are many prescriptions for needs assessment and task analysis, such as those by Carlisle (1986), Kaufman and English (1979), Reigeluth and Merrill (1980), and Rossett (1987). There exist a multitude of prescriptive theories and models to deal with the design of each small piece of instruction (Joyce & Weil, 1980; Reigeluth, 1983b, 1987) and two prevailing approaches to the sequencing of these pieces (cumulation and elaboration). John Keller (1983) has developed the ARCS model for "motivation by design", which prescribes methods for organizing and presenting instruction to increase student motivation. The acronym ARCS is derived from the four types of motivational strategies identified by Keller: attention strategies, relevance strategies, confidence strategies, and satisfaction strategies. Keller suggests that designers overlay these strategy components on instruction where necessary to provide these four different kinds of motivation for students. The strength of Keller's proposals lies in the inclusion of motivational components throughout the design of instructional resources and in recognizing that different *kinds* of motivational strategies are required in different circumstances. An example of a relevance strategy would be the inclusion of mathematics word problems where the textual material was purposefully designed to relate to the student's life experiences. We, in Canada, often encounter the opposite where many textbooks use American examples that are often far from the experience base of Canadian students.

Lacking is an organized knowledge base for the missing middle: how to organize the notions identified through needs assessment and task analysis to create an appropriate set of learning experiences for our students. How can we customize the structure of these learning experiences to provide an optimal path for each student?

A new term has surfaced recently to denote integrated student-centered learning environments: learning systems (Canadian Centre for Learning Systems, 1989; Hathaway, 1989). A learning system differs from an instructional system in a fundamental way. The emphasis in instructional systems design has typically been on the instruction. The underlying assumption occasionally goes so far as to state that if only we can devise perfect instruction, any failure to learn is due to a faulty learner (Engelmann & Carnine, 1982). Learning systems, in contrast, generally share the common goal of providing more student-centered instruction. The focus shifts from providing good instruction to fostering learning. Banathy (1987) provides an example of a shift in the philosophical position and policies in education required to develop a system where the learning experience is the primary level. He describes four types of instructional systems which range from institution centered (type A) through instruction centered (type C) to learner centered (type D). In his "Model D" instructional systems design, "the learner is the key entity and occupies the nucleus of the systems space of education" (p. 103). A learning system is a type D system.

The Triple E

There are three qualities which can be used to evaluate instruction; is it efficient, effective, and enticing (Reigeluth, 1983a; Snelbecker, 1985)? The goal of quality instruction should be to maximize each of these characteristics. However, an issue that is not often addressed is from which perspective should these be optimized? From the perspective of the institution? The faculty? The public? The students? The choice of perspective will quite obviously have a considerable bearing on the decisions reached by educational leaders. Learning systems are designed with the focus as much as possible on the student. As Banathy (1987) says, the students take primacy.

Parts of a Learning System

In *Instructional Design Theories and Models,* Reigeluth (1983b) defined five parts of an educational system: curriculum, instruction, counseling, administration, and evaluation. Reigeluth now agrees that there is a sixth important part: organizing strategies for student progression through a collection of learning experiences (C. M.

Reigeluth, personal communication, 1989). This area of education, when related to the design of learning systems, is being called *instructional logistics*. This term has been chosen to avoid confusion between management in an administrative sense (which Reigeluth defines as one part of *instruction)* and management in the sense of guiding a learner along a path through a sequence of learning experiences.

In light of this, a student-centered learning system requires, among other things, three important parts: a collection of instructional resources (a way to provide educational experiences), an instructional management system (a means of pointing a student to appropriate resources at optimal occasions), and a home base (an advisor and central point of contact for the student). This notion of a home base becomes more significant in nontraditional learning environments, where there is less (or no) contact with a live teacher. The domain incorporating instructional management and the home base is included within instructional logistics.

The Three Souls

In the component display theory, Merrill (1983) defines four kinds of content: facts, concepts, principles, and procedures. An underlying principle of the component display theory is that different types of content require different instructional strategies. Knowledge engineers differentiate between two kinds of knowledge: declarative knowledge, which is knowledge about something, and procedural knowledge, which is knowledge about how to do something (Nelson, 1989).

Procedural knowledge is that which allows us *to do*. Declarative knowledge is that which allows us *to know*. Bloom (1985), in *Developing Talent in Young People*, describes how a young piano player *becomes* a pianist or an athlete *becomes* a tennis player. Their talent changes the essence of their being. This is the understanding which allows us *to be*. Robert Browning (cited in Rowntree, 1987) has a poem titled *A Death in the Desert* which expresses the three parts of one's soul: that which does, that which knows, and that which is. Three men, one soul.

If Merrill's (1983) proposition that different types of notions require different types of instruction can be applied to declarative and procedural knowledge, then the design of learning systems must also account for these three aspects of understanding: to-be, to-know, and to-do. This vision of education includes the declarative and procedural domains plus the to-be domain. Therefore, it requires a synthesis of prescriptions from not only the declarative and procedural domains, but also domains such as motivation (Keller, 1983) and affect (Martin & Briggs, 1986), which relate more directly to the to-be part of education. Keller's ARCS model for motivation by design provides a theoretical model of motivation and a number of motivation strategy components that can be overlaid on instruction. Martin and Briggs have developed links between the cognitive and the affective domains. One particularly significant proposition in this work is that learners cannot be evaluated individually on attitudes because the act of overt evaluation eliminates free choice, which is the essence of attitude. When an individual student knows that assessment of an attitude is going to occur as a part of the instruction, the student is obliged to mimic the attitude in order to pass the test. Martin and Briggs suggest that rather than assessing whether individual students are changing their attitudes, it is necessary to assess whether the instructional program is producing a change in attitude across the group.

Other Concerns

The knowledge base that comprises our understanding of the domain of instructional technology has experienced substantial growth and a shift in emphasis in the last decade due to influences such as the development of promising new technologies like interactive videodiscs and computers in education and the general shift from a behaviorist to a cognitivist perspective (Nelson, 1989). One outcome is an increased interest in the development of computer-managed learning (Baker, 1978; Jones & Massey-Hicks, 1987) and technologically enhanced learning systems (Hathaway, 1989). Baker deals mainly with the technical problems which surrounded computer implementations a decade ago. He also addresses substantive questions regarding the theoretical basis of computer-managed learning. Jones and Massey-Hicks proposed the development of an expert system sitting on top of a computer-managed learning system (from Computer Based Training Systems [CBTS] in Calgary, Canada) to advise course designers in developing instruction. This system was developed by CBTS and the Alberta Research Council, but has not been implemented. The original CBTS computer-managed learning system is primarily a computer test generating and scoring system which does little to manage learning other than shuffle students along a primarily linear track. Hathaway suggests, as a foundation strategy for sweeping educational reform, using commercially available software programs such as spread sheets and project management packages as tools to manage learning experiences in what he terms *technologically enhanced learning systems.*

Overlap between the investigations of the artificial intelligence community in areas like knowledge engineering (Nelson, 1989), the use of programming languages and micro worlds as teaching tools (Papert's LOGO studies out of the MIT Artificial Intelligence Laboratory, 1980), and expert systems as instructional tools (Lippert, 1989) have resulted in pockets of insight not previously considered in the broad educational technology community. This work has not found its way into the design of learning systems.

There is a paucity of systematic knowledge in the literature to address questions of how best to partition a curriculum into manageable and meaningful pieces, to organize the pieces into an optimal set of learning experiences, and to manipulate the progress of a student through those pieces in an optimal way. The theoretical underpinnings of a unified approach to learning system design depend heavily on just such a knowledge base.

Partitioning the Curriculum

As noted above, the selection of appropriate subject matter to develop an educational program has been addressed through needs assessment and task analysis. The issue of identifying pieces of content is addressed with some sophistication by the DACUM people in their curriculum development process (Nolan, 1990). DACUM is an acronym for develop a curriculum, and is a procedure for defining the competencies that are required by beginning practitioners in an occupation. For the "to-do" part of the curriculum, DACUM facilitators assemble a group of practitioners who describe in detail what they do in their job. These job-related tasks are listed in a curriculum skills profile, which is a graphical representation of the tasks which comprise the occupation. This process is used to partition the curriculum into pieces that make sense to practitioners. However, this partitioning is done in isolation from any instructional concerns. The development of a particular set of courses from the curriculum profile seems to be mainly an intuitive process. In addition, the focus in the DACUM process, due partially to its roots in competency-based education, is almost totally on the training "to-do" domain. The "to-know" and "to-be" domains are largely ignored and, in some cases, purposefully omitted from DACUM curricula.

The fundamental question still remains: how to divide up a curriculum into appropriately sized pieces. Bloom (1976) recognized this problem while formulating his mastery learning strategies and suggested a unit that has some independent existence and forms some separable whole. Beyond this he was not specific.

Mental Models

This notion of meaningful pieces of content forming the basis upon which to partition a curriculum bears close resemblance to a mental model as described by Minsky. In *The Society of Mind,* Minsky (1985) provides an explanation of how our minds function. Fundamental to this explanation is the concept of a mental model. Minsky believes that we create cognitive representations of reality by relating new perceptions to previous knowledge structures.

A mental model is the cognitive representation that we create in our mind to explain things that we encounter. It is an internal representation of reality. Our mental models are what allow us to interpret the world and to make sense of our perceptions. The concept of a mental model is a plausible explanation of the structure of our mind (Minsky, 1985).

This view provides a promising insight into prescriptions for determining an optimal way to partition content. Minsky (1985) suggests a unit of understanding might be "a useful and substantial collection of notions" (p. 92). From the domain of computer interface design, Norman (1988) suggests a meaningful piece of content relates to the mental model a novice learner creates. This would appear to be closely related to the larger unit of analysis that Merrill (1989) proposes.

From the perspective of partitioning a curriculum, the smallest appropriate unit of meaningful content might be that which marks the point where curriculum committees lose interest. Above this level, content becomes a value laden topic based on some conception of worth and of interest to "the public." Below this level, content becomes more of a technical concern of interest to educators and designers. This is similar in some ways to the distinction Gagne and Briggs (1979) made between target and enabling objectives. Target objectives appear to be value laden while enabling objectives are technical necessities required to achieve the target.

The network of related ideas, which is also the smallest unit of content that has value in its own right, is called here a "chunque". This spelling is used to avoid confusion with the use of the word "chunk" in a variety of instructional contexts such as chunking individual ideas as a memorization tool. A chunque is a more specific concept to denote a piece of content that consists of a collection of ideas (like facts, concepts, procedures, and principles) and their relationships, which combine to represent a minimal unit of understanding: a useful and substantial collection of notions. It is the cluster of ideas that we use to express and to address our intentions. Understanding is an internal characteristic of a chunque. "We are always chopping complex structures into artificially clear-cut chunks, which we perceive as separate things" (Minsky, 1985, p. 232). When one chunque of understanding is placed in context with other chunques and cross linked to other realms of understanding to form a referential network the result is what Pagels (1988) calls *meaning*: the external characteristic of understanding. Within-chunque ideas and relationships provide understanding. Among-chunque linkages provide meaning. A combination of the two provide meaningful understandings. Within-chunque ideas are the stuff of micro-level strategies: among-chunque contextual links comprise the domain of macro-level strategies (Reigeluth, 1983a).

Instructional logistics is concerned with creating customized paths through learning experiences which are optimal for each learner. These notions about the nature of meaningful understandings and some tentative ideas about how to make them teachable provide a partial basis for instructional logistics strategies at both the level of macro-logistics (among-chunque strategies) and micro-logistics (within-chunque strategies).

If these notions hold promise to inform our design decisions we should investigate their use as tools for learning, as instructional strategies to aid understanding and teachability, and as sequencing strategies to optimize the order in which various aspects of a domain are presented to a learner.

John Seeley Brown (1986) suggests the use of explanatory metaphors to capture how something works and to provide a "seed" upon which to grow a mental model. Novice learners develop a number of context-sensitive models of complex systems. Improvements in performance derive from learning to apply the right model at the right time (Riley, 1986). Eventually, these context-sensitive models coalesce into a single, universally applicable, representation.

diSessa (1986) suggests that an understanding of the way learners form mental models can provide valuable insights into the design of instruction. For example, he recommends that initial instruction might benefit from the use of simplified and partially incorrect representations to aid in initial understanding. Thinking in terms of a structural view of a complex system actually complicates understanding. "Incremental learnability is sacrificed for the sake of uniformity and completeness" (p. 204). There is strong evidence that designing instruction to reflect our use of mental models simplifies understanding (Aronson & Briggs, 1983; Minsky, 1985; Norman, 1988; Riley, 1986). Understanding, according to Riley, is a multidimensional quality rather than something one has or does not have.

This suggests that we should investigate the use of these notions about mental models as a basis for designing learning systems. As Minsky (1985) and Norman (1988) point out, as far as we can tell, people do construct mental models to explain new things. Students are going to construct mental models whether we intentionally build our instruction around them or not. As Norman (1988) suggests,

> We base our mental models on whatever knowledge we have, real or imaginary, naive or sophisticated. Mental models are often constructed from fragmentary evidence, with but a poor understanding of what is happening, and with a kind of naive psychology that postulates causes, mechanisms, and relationships even when there are none. (p. 38)

Manipulating the Pieces

If a curriculum can be partitioned into optimal pieces (chunques) based on the notion of mental models, then a learning system might profitably be designed based on these same notions. What happens within chunques of content might be quite different from what happens between chunques. For example, within chunques, any of a large number of micro-level instructional design models might be applied such as the component display theory (Merrill, 1983), precision teaching (Engelmann & Carnine, 1982), or mastery learning (Bloom, 1976). Between chunques, macro-level organizing strategies such as cumulation (Gagne & Briggs, 1979) or elaboration (Reigeluth & Stein, 1983) provide partial answers.

In a well-organized traditional course the content that comprises the domain can be assumed to be laid out in a logical, sequential, and rigorous fashion that is "correct" in all of its aspects as far as the teacher can determine . The objective is to pass this on, intact, to the student. Perhaps the student needs to acquire quite a different and less formal initial version of the teacher model. A tight, rigid, and rational representation might not be the most appropriate point of contact for a naive learner: "We shouldn't assume that making careful, narrow definitions will always help children 'get things straight.' It can also make it easier for them to get things scrambled up. Instead, we ought to help them build more robust models in their heads" (Minsky, 1985, p. 193). This notion will be expanded in the Appendix.

The Need for a Different Initial Teaching Model

Minsky (1985) suggests that our cognitive representations of reality are not tight logical structures. They are not neat and tidy. They consist of tangled webs of fragments of ideas that are constantly being enlarged, modified, and corrected. We hop around in our minds forming conjectures and faulty explanations based on incomplete and inadequate information. What begins as a tentative model based on naive perspectives and perceptions is gradually reformulated into more accurate, complex, and consistent structures binding together diverse ideas with convoluted threads of meaning.

Why not assist the student in formulating an optimally appropriate mental model to foster meaningful understanding of a domain? Perhaps the collection of learning experiences that are developed to pass on the teacher's body of knowledge and the structures that form the teacher's model should be based on a mental model *specifically designed as a teaching tool* to aid understanding and teachability. This specialized semantic network is tentatively termed an *mnet.* It mediates between the teacher model and the learner model.

An mnet is a special semantic network created for the express purpose of providing an appropriate and optimally learnable representation of a knowledge structure for a novice student encountering a new area of content. An mnet might help bridge the gulf between the existing teacher model and the desired student model. Minsky (1985) says:

> What can we do when things are hard to describe? We start by sketching out the roughest shapes to serve as scaffolds for the rest; it doesn't matter very much if some of those forms turn out partially wrong. Next, draw details to give those skeletons more lifelike flesh. Last, in the final filling-in, discard whichever first ideas no longer fit. (p. 17)

An mnet is a simplified version of the teacher model. It might be what Bruner (1966) had in mind as the initial pass in his learning spirals when he suggested that we can teach anything in some intellectually honest fashion to any student at any age.

The nature of an mnet must be such that it makes learning easier:

> . . . a useful representation must be cognitively transparent in the sense of facilitating the user's ability to "grow" a productive mental model of relevant aspects of the system. We must be careful to separate physical fidelity from cognitive fidelity, recognizing that an "accurate" rendition of the system's inner workings does not necessarily provide the best resource for constructing a clear mental picture of its central abstractions. (Brown, 1986, p. 468)

An mnet is used to transform the complex and rigorous teacher model into a preliminary seed of partial but plausible understandings upon which the student can eventually grow a comprehensive conceptual model.

Macro-Logistics and Mnets

Macro-logistics is the study of instructional strategies concerned with sequencing many ideas. Mnets hold the promise of becoming valuable tools in the design of optimal sequencing strategies in the creation of customized paths through a network of learning experiences. The unit of interest in macro-logistics is the chunque.

Each chunque is a network of ideas that form a somewhat separate mental model. A number of chunques are related in various ways to form higher level mental models much like the different levels of meaning that Minsky (1985) describes. The connections between chunques are the cross-realm correspondences: the external links between mental models. The manner in which chunques are postulated to interrelate is similar to the internal links which connect the nodes within a chunque: It seems to be a matter of scale (Gleick, 1987; Minsky, 1985).

Historically, instructional designers have developed many models of how content should be structured and sequenced. Examples are the cumulation strategy (a parts to whole sequence), the prerequisite strategy proposed by Gagne and Briggs (1979), which Martin and Briggs (1986) describe as a least-complex to most-complex sequence, the spiralling strategy of Bruner (1966), and the elaboration strategy of Reigeluth and Merrill (Reigeluth & Stein, 1983).

Each of these takes a similar tack. The pieces of content are organized into some kind of hierarchical structure and the possible paths through the structure are constrained by the organizing strategy. In some designs the path is linear. In other designs a number of possible path sequences are available. But there are always constraints on the next-chunque choices available to the learner (regardless of whether it is the learner or the teacher who makes the choice).

An omission in the majority of multiple-path designs, however, is a strategy for selecting which of the next-chunque choices is optimal. Merrill (1988) raises this point in his recent work with the ID Expert.

Applying the mnet notions developed in this proposal to macro-logistic path strategies provides some possible guidelines for next-chunque prescriptions. These proposals are based on the elaboration hierarchies used in the Reigeluth-Merrill elaboration theory because a general to detailed, simple to complex structure appears to provide a better framework for the orderly development of an mnet (Reigeluth & Curtis, 1987; Reigeluth & Stein, 1983). This will be explored further in the Appendix.

The elaboration theory organizes pieces of content (similar in nature to chunques) in a hierarchy best expressed by the now familiar zoom lens analogy (Reigeluth & Stein, 1983). The value of this analogy is suggested by Minsky's (1985) comment on an agency in the brain looking in on our thought processes and saying, "This isn't getting us anywhere: move up to take a higher-level view of the situation" (p.92). Or, it might say, "That looks like progress, so move farther down and fill in more details" (p. 92). The possible paths available to students are constrained by next-chunque rules which state that the next-chunque must be either directly subordinate to the current chunque, directly superordinate to the current chunque, or coordinate with the current chunque.

Elaboration hierarchies are based on a single kind of relationship. The nature of the connecting links between the chunques in a given elaboration hierarchy are one (and only one) of either procedural links, conceptual links, or theoretical links. The nature of the links is such that the chunques form a hierarchical structure from simple at the top to complex at the bottom.

The literature on mental models suggests that three extensions to these elaboration structures might accommodate the notions expressed earlier. First, the hierarchical structure might be replaced by a relational network of chunques that still follows a general-to-specific, simple-to-complex design (Locatis, Letourneau, & Banvard, 1990). Second, the constraints that result from the nature of the connections between chunques might be less rigid, incorporating many kinds of cross-realm correspondences. Third, prescriptions for optimal next-chunque choices used to create a path within the constraints of the structure might be based on the significance of the link to the learner.

Customized Instruction

Student-centered learning system design as proposed here includes, as a basic premise, the creation of customized instruction for each learner. Computer-managed learning systems hold the promise of providing just such customized routes for learners. But many have failed to do so (Jones & Massey-Hicks, 1987). Designers of computer-assisted instruction and interactive videodisc instruction use customizing techniques as a matter of course often based, it seems, primarily on intuition. One purpose of this study is to propose a set of prescriptive models to guide the development of such systems. The literature suggests that many of the pieces are in place. They need only to be put together, as Shavelson (1988) suggests, to generate new ways of conceiving some central component of education. Instruction can be customized in two ways. It can be *personalized* to provide instruction to match the desires of the student (primarily a motivational strategy) or it can be *individualized* to match the educational needs of the student (primarily an instructional strategy). In either case, a customized path through a collection of suitable chunques of content must be designed to optimize the learning experiences for that particular learner.

If the path is determined before hand, based on the designer's (or teacher's) best guess at what is appropriate, it is *anticipatory* instruction. If the student's course through the learning experiences is based on actual data on student accomplishments, it is *adaptive* instruction, which results in an interactively designed route for the learner. A path is anticipatory. A route is adaptive.

THE BOOK: CHUNQUES

The Appendix contains the text of the book *Learning Systems Design,* which is the product of this dissertation. It is suggested that this Appendix be read at this time as reference is made to the book throughout the Method section.

METHOD

Gather Information

The plan for gathering current knowledge relevant to instructional logistics and its relationship to instructional design was expanded beyond a review of literature. This plan included the identification of leading researchers in the domain and personal contact with a representative sample of these researchers to discuss the field of instructional management. Attempts were made to procure funding for this study during 1986 and 1987. Through a fortuitous turn of events, a two-year split appointment was obtained as a doctoral program internship. This was as director of research for a community college (the Alberta Vocational College in Calgary, Alberta, Canada) and as project director for an educational center for excellence (the Canadian Centre for Learning Systems in Calgary, Alberta, Canada) This was partially supported through a two-year leave of absence granted by the Edmonton Public School Board. A primary goal at the research center was the development of a series of symposia exploring the field of instruction.

With the assistance of a number of prominent scholars in the field, ten researchers were selected for inclusion in five symposia. A hierarchical conceptual chart depicting the field of instruction and a summary of significant current positions was developed from an extensive literature review conducted between 1983 and 1987 (see section 1.2 in the Appendix). This chart was developed to serve as a structural framework representing the domain of instruction. It represents the very beginnings of a tentative theory of instructional logistics (called *management strategies* at the time). A series of short essays was developed to elaborate and to explain the notions represented in the chart. The resulting booklet was distributed widely throughout the educational community in Canada and the United States with over fifteen hundred copies being published. In addition, the essays and an article describing the application of many of these strategies to an adult basic education program (McArthur, 1987) were published on an electronic conferencing network (TIPNET) at Athabasca University in Alberta, Canada.

Over the course of planning and presenting the five symposia in 1988 and 1989, this chart was reviewed by the various speakers and modified to reflect their views and to incorporate feedback resulting from the electronic conference and booklet. The chart and the resulting discussions with these scholars on the state of current understanding forms the basis of the initial notions incorporated into the design of chunque-based learning systems. Discussions with these leading scholars also provided pointers toward a substantial body of literature from both within and outside the domain of instructional design.

Research Applicable Knowledge from Outside the Field

A considerable body of literature from the domains of artificial intelligence, computer interface design, mental models, the design of everyday things, indeterminate systems, and the study of chaos was reviewed and applicable notions were incorporated into the tentative framework developed earlier. The methodology employed was to request from scholars within the domain the titles of significant works outside the field that might be applicable to instructional logistics. These were reviewed and further leads derived from cited works were investigated. In this fashion, a directed discovery approach was developed with sources provided through direct contact with colleagues providing the initial seed. This fanned out through reference lists into related works.

Organize Findings, Identify Gaps

In 1987 and 1988 a major project was undertaken as part of the internship to develop an alternative delivery system for a large-scale adult basic education program. This package, called PASSPORT (McArthur, 1987), was expected to deliver approximately one hundred modules of content to students in four major sites and a wide range of outreach situations ranging from community learning centers to individuals reached by modem. This project provided an opportunity to try out many of the notions central to the developing theory of the management of instruction by testing how they could be incorporated into a large and complex curriculum project. One result of this was to convince many educational leaders of the potential of the strategies in an intellectual sense. However, as John Seely Brown (1986) suggests, it is a different matter altogether to change what people actually do. This project was abandoned.

During 1988 and early 1989 the body of knowledge uncovered during the previous years was organized into a number of fragmented models related to the management of instruction. This was initially done by developing a great number of single-concept essays and short notes (similar in design to the old single-concept film loops of the sixties). These were stored in three forms: as hard copy single-page printouts, as a large computer outline on a word processor, and as charts on innumerable whiteboards.

The single-page printouts provided the most successful method of reviewing and editing individual clusters of notions. The computer based outline, which provided facilities for collapsing text under headings and easily reorganizing the headings, provided a very flexible method of shuffling the ideas around. The whiteboard charts began as parts-of conceptual hierarchies for fragmented notions. These soon became too complex to manage. In addition, it was discovered that there are infinite ways to organize and structure the notions which are not especially helpful in developing an integrated vision.

Each of the three ways of representing the domain provided essential tools for reformulating the notions and for making sense of these notions, but there was no representation of the multiplicity of *kinds of links* which connected the fragmented ideas. At this point the notion of converting the hierarchical conceptual structures to relational networks was discovered (Denenberg, 1988), along with Brown's (1986) idea of partial mental models forming the seed upon which to grow more comprehensive and complete models. These notions became not only the solution to the problem of structuring the instructional logistics strategies, which contribute to chunque-based learning systems, but also became the central notion around which this work has evolved.

Figure 1 is a sample of a relational network that evolved during the development of the chunque theory. It defines some of the nodes and links that made up my vision of the domain early in my work as this model evolved. This network is

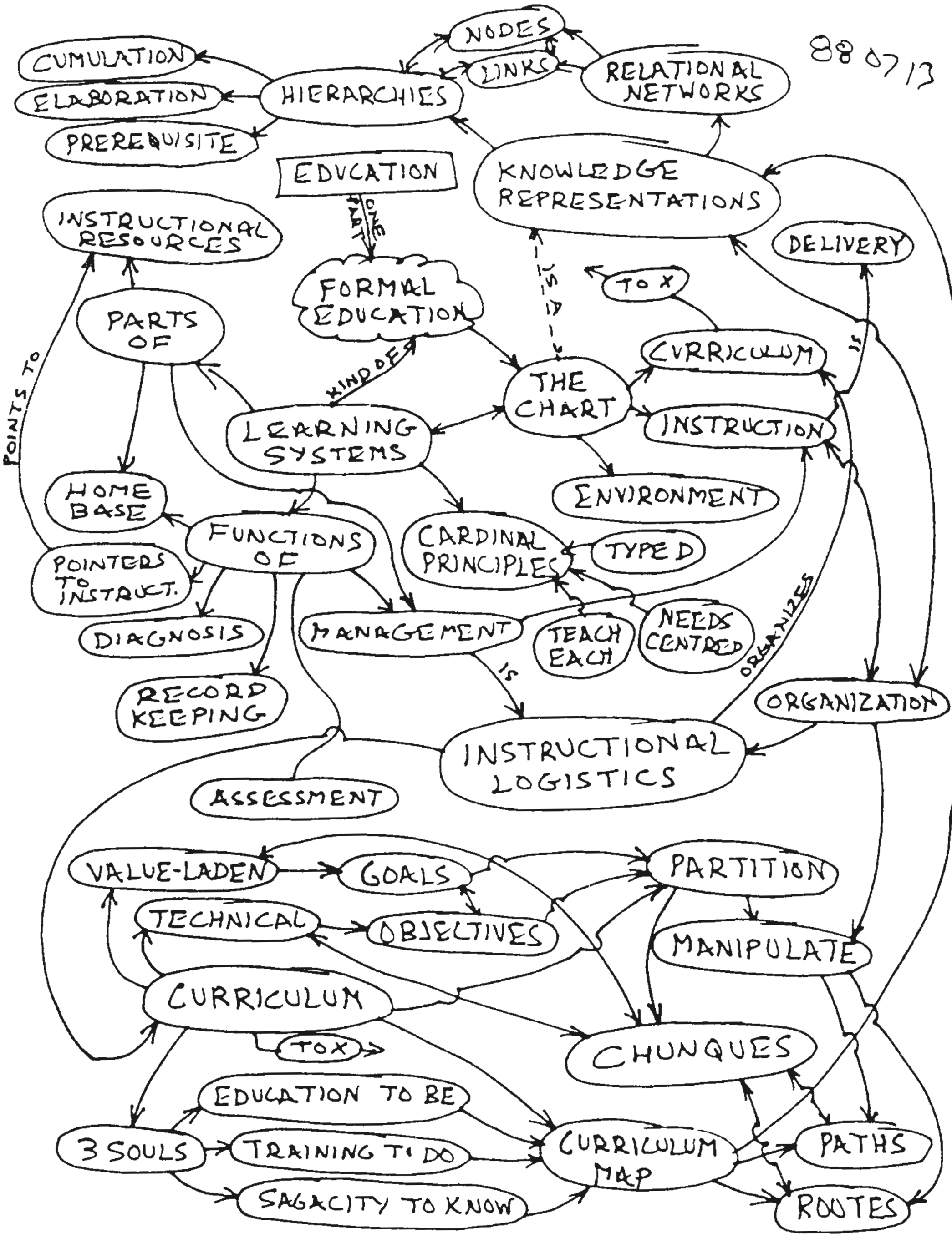


Figure 1. Tentative relational network for learning systems design.

included only as an example of one stage of how the model developed: It is not intended to illustrate any sort of cohesive vision of learning systems.

It is fascinating that, even though the intention was to shift from a hierarchical representation to a relational network that would depict the *kinds of relationships* among the nodes, I still did not write these down but continued to carry most of them in my head. Note also that some of the nodes might more correctly be thought of as links, such as the node "parts of" in the upper left corner of the figure. It is also interesting to compare this to the chart (in Section 1.2 of the Appendix), which was being developed at about the same time.

Three Problems

Throughout the process of gathering the notions that make up chunque-based learning systems three particular problems repeatedly surfaced: finding closure, limiting the scope of the work, and creating an appropriate format for the results. Robert Persig (1984) postulates that one of the fundamental problems with the scientific method is that, while it was intended to provide answers, the more closely one investigates a particular problem the more one discovers that there are no answers: just more questions. The scientific method does not usually produce the expected closure. In exploring the propositions that make up chunque-based learning systems, closure was as elusive as that described by Persig in his quest for the meaning of quality. This problem was resolved by focussing on a broad sweep across the notions that make up instructional logistics rather than an in-depth investigation of each. This is in keeping with the development of speculative theory and with the notions relating to mental models as tools for learning. The result was more of a holographic image where the scope is broad but the definition may at times be faint.

The empirical approach to experimental research follows a course which proceeds in a logical progression from the identification of a problem through the formulation of a hypothesis, the testing of the hypothesis, the evaluation of research results, and the development of explanatory conclusions. This is the "bricks which form the temple of knowledge" approach to theory building. This also prescribes a scope which is narrow, but deep. As one of the primary goals of this dissertation was to develop an integrative theory, the scope must, by definition, be broad. However, in trying to satisfy the conflicting goals of a broad perspective and the traditional process to empirical research, the scope of the project rapidly exceeded the resources available to one theorist. To limit the scope of this work to manageable proportions, while maintaining the goal of integrative theory building, the notions of speculative theory were employed to delimit the depth of the process. The steps in the process were limited to gathering information applicable to instructional logistics (from a broad base including personal experience, recent literature, personal contact with instructional theorists, and participation in conferences and symposia) and synthesizing the notions relating to instructional logistics into a number of propositions and relationships which form an appropriate mental model.

This process emphasized the aspects of the work relating to theoretical research, but limited the scope to a check of plausible and logical validity such as that defined by Gropper (1983b), by House, Mathison, and McTaggart (1989), and by Reigeluth (1983a). The work specifically excludes an empirical research component. However, most of the strategy components which make up this integrative and speculative theory have been validated (in isolation) through empirical studies and many, such as mastery learning (C.-L. C. Kulik, J. A. Kulik, & Bangert-Drowns, 1990), are recognized as exemplary prescriptive strategies. References to these studies form a major part of the content footnotes.

This work emphasizes the integration of these many fragmented components into a cohesive, plausible, and testable (but sometimes untested) whole. It is intended to illuminate Shavelson's (1988) new mindframe, Tazelaar's "whole new way of looking at things" (1990, p. 206), or a new paradigm in Kuhn's (1970) sense.

Knowing when to stop, while pursuing an integrative vision of a domain, relates to Persig's (1984) notions about closure. Every journal article and every conversation may provide new grist for the speculative theorist's mill. The gathering of ideas for chunque-based learning systems began in earnest in 1985. It ended October 1, 1990, on page 206 of Tazelaar's (1990) article in *Byte*.

The problem of devising a format to organize and present the notions that comprise this vision of instructional logistics remained a thorny problem from the beginning of the exercise until the spring of 1989. Marvin Minsky's (1985) marvelous book *The Society of Mind* provided the genesis of a solution. In his book Minsky presents his views on how our minds work through a series of single page essays, each describing one small facet of his vision. Each essay stands alone but combines with the others to create strands of meaning. In relation to the previous discussion of mental models and the distinction between understanding and meaning, each essay provides understanding of a collection of notions while together they form the linkages that foster meaning in a wider context. Each page is a transaction with the reader. These transactions are clustered into sections and the sections sequenced to unfold an appropriate and meaningful explanation of Minsky's societies of mind.

This book was patterned after Minsky's (1985). Notions are formulated as single page essays which stand alone. Together these essays comprise a unified picture of the strategy components that make up chunque-based learning systems. The format of single page essays was chosen partly to address the issue of a modular theoretical position where relatively independent and stand-alone notions can be presented on individual pages. This opens up the possibility of replacing particular strategy components with updated versions as the instructional logistics knowledge base evolves. In addition, this format was chosen with a view towards electronic publishing where conventional wisdom dictates that short essays are more accepted and accessible to users than long documents. This proposition has certainly been supported with the electronic publishing of works associated with this study. The responses (in the form of comments) to short pieces on the TIPNET electronic conferences far outnumbered those for longer works.

The literature review was integrated within the text in the form of content footnotes to make the story line more readable to those who are more concerned with the substance of the work than with the sources. In some cases, extensive references and explanations are included in these content footnotes. The intent is to provide a layered source of information where some readers will chose to read only the body text, while others can delve into both source citations and elaborations of the primary notions in the text.

How many of these discoveries came about remains a mystery. It would appear that they are the result of intensive and continuous mental reformulations of the three knowledge representations described earlier: single page essays, computer manipulated outlines, and fragmented relational networks. There is no doubt that extensive discussions with colleagues, clients, and coworkers drove the clarification process. The essential notion of the *chunque* was simply *there* one day in a donut shop while discussing an essay on management strategies. Many other central notions appeared, unannounced, in the middle of the night. The theory construction process in this instance followed both an inductive and a deductive approach. It was an eclectic transformation of Minsky's (1985) tangled webs brought on, in part, by the parallel transformation of this researcher from a *student of* instructional management to an Eisnerian connoisseur.

Reconsidering the Pieces

At this time, (and since September of 1989) the notions incorporated into chunque-based learning systems are being applied to curriculum and instruction at Lakeland College in Northeastern Alberta and Northwestern Saskatchewan in Canada through the Department of Learning Systems in the Division of Program Services. I am currently serving as Coordinator of Learning Systems responsible for the quality of curriculum and instruction across the institution. This has provided a valuable shift in perspective from the primarily alternate delivery and computer-managed learning posture of the initial studies and has illuminated many aspects of the application of instructional management strategies within a traditional college setting. This has become a valuable opportunity for review and reformulation of many strategy components from a new perspective.

RECOMMENDATIONS

Nature of the Links

The relational network that provides the framework for instructional logistics is a tentative initial representation. Continuing theoretical research is required to make this model more robust through the identification of the nature of the links between its parts. As I noted in Part Ten of the Appendix the field for instructional design appears to have a knowledge base which emphasizes the nodes more than the links.

More research from other domains such as knowledge acquisition and expert systems may prove productive in uncovering a more extensive knowledge base to aid in the development of more helpful ways of viewing the relationships in this model.

In a related sense, with extended understanding of the nature of relationships in semantic networks, the structure of the model may also become more robust as this understanding is incorporated into the design. Riley (1986) points out that our models of reality start out anchored to specific situations. It is only with increased understanding that these models become more general and applicable to a wider variety of circumstances. Note that this does not imply that the goal is to create one model that applies to all situations. As Joyce and Weil (1980) suggest, we need a multitude of different models of teaching and of the management of instruction tailored to meet the needs of different students in different circumstances.

Improve Nodes

One of the shortcomings of this representation of instructional logistics and learning systems is the limited array of strategy components that have been included as nodes in the structure. I believe there is a need to incorporate a much greater number of alternative strategy components within each node. In this way, a wider range of choices will be available to the learning systems designer to customize the learning experiences to match the needs of the students. This aspect of theory construction is what I consider to be at the heart of theoretical research: the discovery of other existing models and strategy components that can be incorporated within a more global structure. As Kuhn

(1970) points out, our paradigms expand to include newly uncovered principles and prescriptions until a point is reached where the old structure can no longer accommodate them all. Then a new and more appropriate paradigm will replace the old.

Development Model

At Lakeland College my work is currently centered on creating an instructional development model based on the chunque theory. I believe that considerable further research is required to formulate optimal ways of implementing many of the propositions which make up instructional logistics and chunque-based learning systems. As Brown (1986) suggests:

> It is easy to give talks about abstract ideas and even to get folks to understand them "intellectually," but it is quite a different thing to have ideas actually affect people's beliefs, actions, and ways of thinking about a given problem. (p. 480)

Refine Definitions

The electronic glossary of instructional design terminology being developed at San Diego State University is based on having a number of different definitions of the same terms drawn from diverse sources. A multitude of theorists and practitioners can add definitions either of their own creation or drawn from research and literature that they have encountered. Editors would then create one or more "official" definitions of the terms based on the collection of usages drawn from the field. Users can access either the databank of individual contributions (which include citations) or the "official" definitions.

In my developmental work with the glossary project I input approximately two hundred terms from current textbooks into the citation database. My continuing work with instructional logistics is expected to include adding the terms from this work to the glossary.

Electronic Conferencing

How can our profession address the problem of incorporating new developments into a theory such as this? At the Canadian Centre for Learning Systems an electronic publishing model was developed which addresses these issues. In a joint project with Athabasca University an attempt was made to put together an electronic conferencing system that contained articles such as those that formed the foundation of this work.

It failed to get off the ground, partially because the Canadian Centre for Learning Systems was torpedoed at the time we set it up and we were aware that the project would die, and partially because we could not seduce enough participation. This was due primarily to technical problems accessing the system, especially from the United States. However, I feel that this idea of a growing model, developed in concert with many scholars, holds great promise. It may be one potent way of addressing Reigeluth's (1983a) call for more integrative work to bring together into one body of understanding (and meaning!) much of the diverse work which is being done.

This is one reason the text of this work is page based. If each notion can be expressed on a single page, then each can be scrutinized in isolation but related into the broader content of the work as a whole. Also, each page can be incorporated into an electronic conference, perhaps someday in a hypertext system with referential links, like a bowl of instructional logistics spaghetti and meatballs which grows through the contribution of many scholars. As a start, my version of this work resides not in print but on disc. It is a different version than this one. It has become a living theory, but only for me. This would have been impossible a decade ago as it could not have been done without a computer. But it can be done now, not only as a personal version accessible to only one theorist, but to many. The technology is in place through systems like Byte magazine's BIX conferences. This would be a good project for the future!

A further discussion of future directions in theoretical research is contained in Part Eleven: Afterword, in the Appendix.

REFERENCES

Adams, D. (1990). *Hitch hiker's guide to the galaxy.* New York: Penguin Books.

Adler, M. J. (1982). *The paideia proposal: An educational manifesto.* London: Collier Macmillan.

Aronson, D. T., & Briggs, L. J. (1983). Contributions of Gagne and Briggs to a prescriptive model of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 80-100). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart, Winston.

Baker, F. B. (1978). *Computer managed instruction: Theory and practice.* Englewood Cliffs, NJ: Educational Technology Publications.

Banathy, B. H. (1987). Instructional Systems Design. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 85-112). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives, handbook I: Cognitive domain.* New York: David McKay.

Bloom, B. S. (1968, May). Mastery learning. In *Evaluation comment* (Vol. 1, No. 2). Los Angeles: University of California at Los Angeles, Center for the Study of Evaluation of Instructional Programs.

Bloom, B. S. (1976). *Human characteristics and school learning.* New York: McGraw-Hill.

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13* (6), 4-16.

Bloom, B. S. (Ed.). (1985). *Developing talent in young people.* New York: Ballantine.

Branson, R. K., & Grow, G. (1987). Instructional systems development. In R. M. Gagne (Ed.), *Instructional technology: Foundations.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Bronowski, J. (1956). *Science and human values.* New York: Harper and Row.

Brown, J. S. (1986). From cognitive to social ergonomics and beyond. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 457-486). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bruner, J. S. (1966). *Toward a theory of instruction.* New York: Norton.

Burns, H. L., & Capps, C. G. (1988). Foundations of intelligent tutoring systems: An introduction. In M. C. Polson & J. J. Richardson (Eds.), *Foundations of intelligent tutoring systems* (pp. 1-19). Hillsdale, NJ: Lawrence Erlbaum Associates.

Canadian Centre for Learning Systems. (1989). *Mission, goals, and programs.* Calgary, Alberta: Author.

Carlisle, K. (1986). *Analyzing jobs and tasks.* Englewood Cliffs, NJ: Educational Technology Publications.

Checkland, P. B. (1981). *Systems thinking, systems practice.* New York: Wiley.

Checkland, P. B. (1981). *Soft systems methodology in action.* New York: Wiley.

Clark, B. R. (1989). The academic life: Small worlds, different worlds. *Educational Researcher, 18* (5), 4-8.

Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19* (6), 2-10.

Davidson, D. (1984). *Inquiries into truth and interpretation.* New York: Oxford University Press.

Denenberg, S. A. (1988). Semantic network design for courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 307-326). Hillsdale, NJ: Lawrence Erlbaum Associates.

diSessa, A. A. (1986). Models of computation. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 201-218). Hillsdale, NJ: Lawrence Erlbaum Associates.

Draper, S. W. (1986). Display managers as the basis for user-machine communications. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 339-352). Hillsdale, NJ: Lawrence Erlbaum Associates.

Eisner, E. W. (1985). *The educational imagination* (2nd ed.). New York: Macmillan.

Engelmann, S., & Carnine, D. (1982). *Theory of instruction: Principles and applications.* New York: Irvington.

Fleming, M., & Levie, W. H. (1978). *Instructional message design: Principles from the behavioral sciences.* Englewood Cliffs, NJ: Educational Technology Publications.

Fraser, W. A., Sir. (1902). *Words on Wellington: The duke -- Waterloo -- the ball.* London: Nimmo.

Gagne, R. M. (1987). Introduction. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 1-10). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gagne, R. M., & Briggs, L. J. (1979). *Principles of instructional design* (2nd ed.). New York: Holt, Rinehart, Winston.

Gleick, J. (1987). *Chaos: Making a new science.* New York: Viking Penguin.

Gropper, G. L. (1983a). A behavioral approach to instructional prescription. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 101-161). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gropper, G. L. (1983b). A metatheory of instruction: A framework for analyzing and evaluating theories and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 37-53). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hathaway, W. E. (1989). *Education and technology at the crossroads: Choosing a new direction.* Edmonton, AB: Planning and Policy Secretariat, Alberta Education.

Hawking, S. M. (1988). *A brief history of time: From the big bang to black holes.* New York: Bantam.

House, E. R., Mathison, S., & McTaggart, R. (1989). Validity and teacher inference. *Educational Researcher, 18* (7), 11-15, 26.

Jackson, P. W. (1990). The functions of educational research. *Educational Researcher, 19* (7), 3-9.

Jones, M., & Massey-Hicks, M. (1987, November). *Expert CML: The next generation.* Paper presented at the Computer Assisted Learning in Tertiary Education Conference, Sydney, Australia.

Joyce, B., & Weil, M. (1980). *Models of teaching* (2nd ed.). Englewood Cliffs, NJ: Educational Technology Publications.

Kaufman, R., & English, F. W. (1979). *Needs assessment.* Englewood Cliffs, NJ: Educational Technology Publications.

Keller, F. S. (1968). "Good-bye teacher . . ." *Journal of Applied Behavioral Analysis, 1*, 79-89.

Keller, F. S., & Sherman, J. G., (1974). *The Keller plan handbook.* Menlo Park, CA: Benjamin.

Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum Associates.

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

Kulik, C.-L. C., Kulik, J. A., & Bangert-Drowns, R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research, 60* (2), 265-299.

Kulik, J. A., Kulik, C.-L. C., & Bangert-Drowns, R. L. (1990). Is there better evidence on mastery learning? A response to Slavin. *Review of Educational Research, 60* (2), 303-307.

Lampert, M., & Clark, C. M. (1990). Expert knowledge and expert thinking in teaching: A response to Floden and Klinzing. *Educational Researcher, 19* (5), 21-23.

Laurel, B. K. (1986). Interface as mimesis. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 67-85). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lippert, R. C. (1989). Expert systems: Tutors, tools, and tutees. *Journal of computer based instruction, 16* (1), 11-19.

Locatis, C., Letourneau, G., & Banvard, R. (1990). Hypermedia and instruction. *Educational Technology Research and Development, 37* (4), 65-77.

Mark, W. (1986). Knowledge-based interface design. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 219-238). Hillsdale, NJ: Lawrence Erlbaum Associates.

Martin, B. L., & Briggs, L. J. (1986). *The affective and cognitive domains: Integration for instruction and research.* Englewood Cliffs, NJ: Educational Technology Publications.

McArthur, I. (1987). *Passport instructional logistics.* Calgary, Alberta: The Canadian Centre for Learning Systems.

Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

Merrill, M. D. (1988). An expert system for instructional design. *IEEE expert*, Summer, 25-37.

Merrill, M. D. (1989, June). Paper presented at the annual convention of the Association for Media and Technology in Canada, Edmonton, Alberta.

Merrill, M. D., Li, Z., & Jones, M. K. (1990). Limitations of first generation instructional design. *Educational Technology, 30* (1), 7-11.

Merrill, P. F. (1987). Job and task analysis. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 141-173). Hillsdale, NJ: Lawrence Erlbaum Associates.

Millman, J. (1989). If at first you don't succeed: Setting passing scores when more than one attempt is permitted. *Educational Researcher, 18* (6), 5-9.

Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster.

Nelson, W. A. (1989). Artificial intelligence knowledge acquisition techniques for instructional development. *Educational Technology Research and Development, 37* (3), 81-94.

Nolan, T. D. (1990). *The DACUM process training manual.* Cincinnati, OH: Cincinnati Technical College.

Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books.

Norman, D. A., & Draper, S. W. (Eds.). (1986). *User centered systems design: New perspectives on human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Pagels, H. R. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity.* New York: Simon and Schuster.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* New York: Basic Books.

Persig, R. M. (1984). *Zen and the art of motorcycle maintenance* (2nd ed.). New York: Morrow.

Quine, W. V. O. (1960). *Word and object.* Cambridge: M. I. T. Press.

Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. (Ed.). (1983b). *Instructional-design theories and models: An overview of their current status.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. (Ed.). (1987). *Instructional theories in action: Lessons illustrating selected theories and models*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M. & Curtis, R. V. (1987). Learning situations and instructional models. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 175-206). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. M., & Merrill, M. D. (1980, September). *The extended task analysis procedure (ETAP) user's manual*. Final Report. Submitted to the US Army Training and Doctrine Command (TRADOC), Fort Monroe, VA.

Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates.

Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ross, S. M., & Morrison, G. R. (1989). In search of a happy medium in instructional technology research: Issues concerning external validity, media replications, and learner control. *Educational Technology Research and Development, 37* (1), 19-33.

Rossett, A. (1987). *Training needs assessment.* Englewood Cliffs, NJ: Educational Technology Publications.

Roueche, J. E., & Baker, III, G. (1986). *Access and excellence.* Washington: American Association for Community and Junior Colleges.

Rowntree, D. (1987). *Assessing students: How shall we know them* (2nd ed.). New York: Nichols.

Salomon, G. (1979). *The interaction of media, cognition, and learning.* San Francisco: Jossey Bass.

Shavelson, R. J. (1988). Contribution of educational research to policy and practice: Constructing, challenging, changing cognition. *Educational Researcher, 17* (7), 4-11.

Shuell, T. J. (1990). Phases of meaningful learning. *Review of Educational Research. 60* (4), 531-547.

Simon, H. A. (1981). *The sciences of the artificial* (2nd ed.). Cambridge, MA: MIT Press.

Skinner, B. F. (1971). *Beyond freedom and dignity.* New York: Knopf.

Slavin, R. E. (1990). Mastery learning reconsidered. *Review of Educational Research, 60* (2), 300-302.

Snelbecker, G. E. (1983). Is instructional theory alive and well? In C. M. Reigeluth, (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 437-472). Hillsdale, NJ: Lawrence Erlbaum Associates.

Snelbecker, G. E. (1985). *Learning theory, instructional theory, and psychoeducational design.* New York: University Press of America.

Tazelaar, J. M. (1990). Object lessons. *Byte, 15* (10), 206.

Tennyson, R. D., Welsh, J., Christensen, D. L., & Hajovy, H. (1985). Interactive effects of content structure, sequence, and process learning time on rule-using in computer-based instruction. *Educational Communications and Technology Journal, 33*, 213-233.

Tennyson, R. D., & Christensen, D. L. (1988). MAIS: An intelligent learning system. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 247-274). Hillsdale, NJ: Lawrence Erlbaum Associates.

Tyler, R. W. (1950). *Basic principles of curriculum and instruction.* Chicago: University of Chicago Press. (p.41).

Wilburn, K. (1983). *Holographic paradigms.* Salinas, CA: Intersystems Publications.

APPENDIX

Table of Contents

PREFACE

PREFACE

This book is about designing learning systems. One major feature of the learning systems proposed here is that the path students follow through the instruction can be customized to suit their ability or intentions. The book is divided into a collection of single page essays that outline my vision of student centered learning system design. There are several ways to approach the book. If you read it in order, the sections will hopefully unfold the many complex notions that comprise learning system design as I see it to create a mental model that grows from a simplified seed into a more robust and complex representation.

However, it is also possible to explore selected topics without reading every section. In the next section I have listed a few sets of related sections which address various issues drawn from learning systems design. If you read these sections in the order given, you should gain an introduction to the title topics.

Finally, in Section 1.7 there is a relational network or cognitive map representing many of the individual notions which lie within the pages of the book and the nature of their interrelationships. You might prefer to pick a starting point and browse through the sections along the varied pathways which link these notions. An explanation of the coding which defines the links along these pathways is contained in Section 1.8.

Enjoy yourself.

SOME SELECTED PATHS

Learning Systems Path: 1.2 to 1.9 inclusive, 1.13 to 1.17 inclusive, 1.21, 1.23, 1.24, 1.25, 8.13.

Instructional Logistics Path: 2.1, 2.2, 2.12, 4.1, 4.15, 5.1, 5.12, 7.14, 9.1.

Customized Instruction Path: 1.20, 1.22, 3.1, 3.7, 3.8, 3.9, 3.11, 3.12, 3.15, 3.17, 4.6, 4.7, 4.15, 4.16, 5.2 to 5.7 inclusive, 5.9, 5.10, 5.13, 6.6 to 6.10 inclusive, 6.12, 7.11, 7.13.

Goals and Intentions Path: 3.2, 3.3, 3.4, 3.5, 3.7, 3.8, 3.9, 3.11, 3.12, 3.13, 3.15, 3.17, 5.5, 5.6, 8.2, 8.3, 8.4.

Meaning and Understanding Path: 2.3, 2.4, 2.5, 2.6, 2.7, 2.11, 4.6, 4.11, 7.15, 9.7, 10.13, 10.14, 10.15, 10.19, 10.12.

Curriculum Design Path: 3.1, 3.19, 3.20, 3.21, 4.8, 4.15, 5.12, 6.1 to 6.10 inclusive, 7.1, 7.2.

DACUM Develop A Curriculum Path: 3.20, 4.8, 4.9, 4.13, 6.3, 6.4, 6.7, 7.3, 7.8, 7.10, 9.6.

Chunques and Partitioning the Curriculum Path: 4.1 to 4.7 inclusive, 4.9, 4.12 to 4.16 inclusive, 6.7, 6.8, 6.9, 7.10, 7.14, 8.5, 8.6, 8.17, 8.18, 9.1 to 9.7 inclusive, 9.11.

Knowledge Representation Path: 1.7, 1.27, 2.9, 2.10, 3.18, 3.19, 3.20, 3.21, 4.7, 4.10, 6.1, 6.2, 6.3, 6.4, 6.5, 7.1, 7.2, 7.15, 9.5, 10.1 to 10.20 inclusive.

Mental Models and Instruction Path: 2.8, 2.9, 2.11, 7.15, 9.3, 9.4, 9.5, 10.1, 10.4 to 10.20 inclusive.

Instructional Structures Path: 7.2 to 7.11 inclusive, 9.4, 9.5.

Assessment Path: 1.11, 3.5, 5.14, 5.15, 6.11, 8.1, 8.3 to 8.20 inclusive, 9.13 to 9.21 inclusive, 10.21, 10.22.

Mastery Learning Path: 4.3, 4.4, 4.5, 4.6, 5.12, 8.12, 9.8, 9.9, 9.10, 9.13 to 9.21 inclusive.

Samples and Examples Path: 1.1, 1.10, 1.11, 1.19, 1.20, 2.3, 2.6, 2.7, 3.10, 3.16, 5.7, 5.8, 5.14.

And, finally, my "Most Significant Notions" Path: 1.17, 1.18, 1.20, 2.1, 2.3 to 2.11 inclusive, 3.7, 3.8, 3.9, 3.11, 3.12, 3.15, 3.17, 4.2, 4.6, 4.7, 4.12, 4.15, 5.3, 5.8, 5.9, 5.10, 6.3, 6.4, 6.5, 7.15, 8.2, 8.3, 8.4, 8.19, 9.4, 10.1, 10.2, 10.3, 10.4, 10.10 to 10.15 inclusive.

PART ONE: LEARNING SYSTEMS

1.1 WHERE DID IT ALL BEGIN?

Before I delve into the intricacies of learning systems, I would like to provide an ancient example of one. Back in 1966, when I was an undergraduate student discovering the work of Bruner and Gagne, a new Industrial Arts program was approved for implementation in the Province of Alberta. This program included new goals, a new curriculum, and new facility organization; it was a radical change from traditional shop courses. The goals of this program were to provide exploratory experiences in the productive aspects of society and to provide an introduction to the multiplicity of career opportunities available to the students.[1]

I was hired by the University of Alberta as a Curriculum Technician to design and produce the curriculum materials for this program. It turned out that this also involved the creation of an entire new way of organizing a multiple activity industrial arts program. Four years later, a colleague, Ron Nychka, and I set up a team teaching programmed instruction lab in a large urban high school. The design and implementation of this program, called INSCITE, for **in**dustry, **sci**ence, and **te**chnology, was the genesis of my recent work and of instructional logistics.

The INSCITE program featured approximately sixty different learning experiences, which we called *Learning Modules*, covering a wide variety of industrial processes, ranging from ceramics and plastics to transportation technology. None of these modules was prerequisite to any of the others ... they were all stand alone pieces of curriculum. A student could select any of these, in any order. Instruction was provided by independent instruction print resources (that is 1960's jargon for *handouts*), which directed the students to procedural instruction manuals, slide sets, or video segments. Embedded into the learning modules were short answer questions and checkpoints, where the student had to get an instructor's initials before carrying on.

The development of this program raised many questions about how to organize and operate such a program. Questions such as: When should the student decide what to do, and when should the teacher decide? How do you pick what to do next? How many ideas should be included in a module? What should the instruction inside a module look like? Out of these questions grew the notion of instructional logistics, the topic of this work. I will explore ideas and propositions that can provide guidance in designing *learning systems* that are student centered, and which can provide customized learning experiences appropriate for the ideas we want to instill in our students, the characteristics of the students, and the circumstances which constrain our efforts.

---

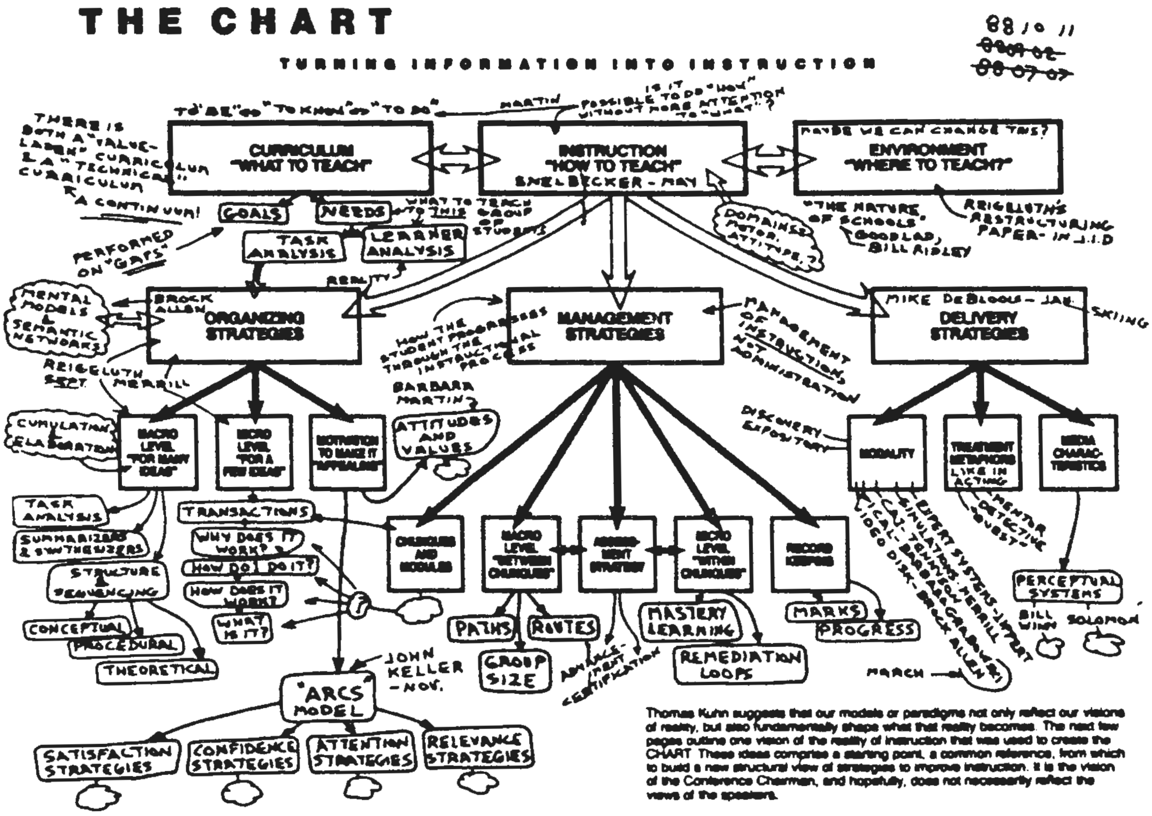
1 Dr. Henry Zeil came to Alberta from a labour union background in the U. S. to provide the driving force for this radical new approach to industrial arts education in the public school system.

1.2 THE CHART: A VIEW OF EDUCATION

Many years later, at The Canadian Centre for Learning Systems, a center for excellence in education, we ran a symposium series dealing with the latest theoretical developments in instruction. We put together a conceptual chart depicting the field of instruction from an extensive literature review conducted between 1983 and 1987. This chart was developed to serve as a structural framework depicting the domain of instruction, and represents the very beginnings of a tentative theory of instructional logistics (called *management strategies* at the time).

We asked a group of our colleagues to help us select ten leading scholars in instructional design to act as the speakers for our symposia.[2] A draft version of this chart was sent to each of them, and with their help it was modified and tuned up to reflect their views of instruction.

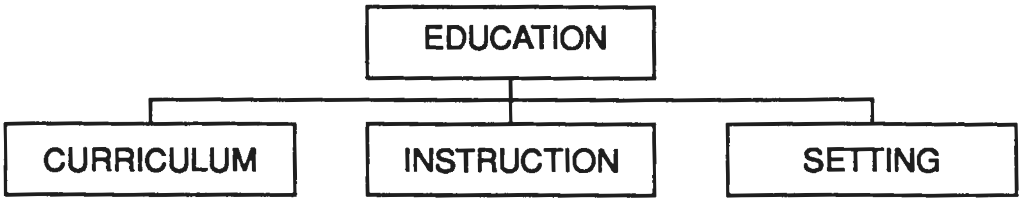
This is what we ended up with:



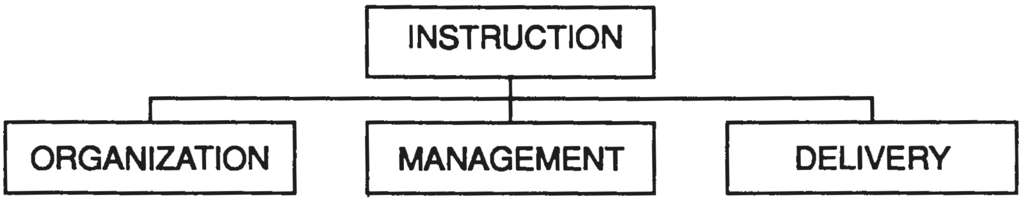
2 The scholars participating in this project during 1987 and 1988 were Brock Allen (San Diego State University), Ken Carlisle and Michael DeBloois (Miken Communications), Barbara Grabowski (Syracuse University), John Keller (The Florida State University), Barbara Martin (Kent State University), David Merrill (Utah State University), Charles Reigeluth (Indiana University), Allison Rossett (San Diego State University), and Glenn Snelbecker (Temple University). The symposium was run for The Canadian Centre for Learning Systems by myself (at that time Director of Research with the Alberta Vocational Centre in Calgary) and Janet McCracken, now with the Alberta Research Council.

1.3 ONE VIEW OF THE DOMAIN OF INSTRUCTION

The top section of the chart illustrates our division of the domain of education into three parts: curriculum, instruction, and setting. We described these as "what to teach," "how to teach it," and "where to teach it."



Instruction, the *how to teach it* part, was the focus of our work at The Canadian Centre for Learning Systems. We split instruction into three pieces that we were fairly confident would prove valuable in looking at the workings of instruction: the *organization* of subject matter, the *management* of instruction, and the *delivery* of instruction.



As we began to analyze each of these parts, our confidence level dropped as we discovered that many scholars saw the domain of instruction from very different perspectives. Our vision grew cloudy. So we started drawing clouds.

The freehand parts of the chart on the previous page reflect areas where we felt less certain that our scholars and the participants in the symposia held a common vision. The more closely we looked at an area, the more overcast our theoretical sky became until we reached the point where we knew there were clouds, but we did not have much information about them. So we drew clouds without terms attached.

Two very good things resulted from this work. We ended up with a depiction of the field of instruction that was a conglomerate of the vision of a number of ranking theorists, and we realized that there was much common ground in their understanding, but a diversity of ways to depict the relationships among the pieces. I later discovered the term *fuzzy logic* from artificial intelligence which was certainly an appropriate description of the organization of the chart.

There was (and is) a comprehensive vision of instruction held by each of these scholars, and each vision has much in common with the others. Our chart is a melding of these visions into a framework for developing some tentative theories regarding instruction and its place within formal education. The propositions which will unfold over the course of this journey through learning systems design are constructed on this foundation.

1.4 THE SPONGE, THE FUNNEL, AND THE FLOWERPOT

Back even further during my undergraduate days, a long forgotten professor used an apt metaphor to describe varying perspectives on the nature of education. He suggested that some educators view the student in a posture with his head tipped to one side and a funnel stuck in his ear. These educators see knowledge as an infinite fountain from which they draw an appropriate pitcherful. They pour into the funnel as much knowledge as will fit into the student's head. If they pour too little, the student has not reached his potential. If they pour too much, it overflows and is lost.

Another vision of education sees the student as a sponge. The educator pours the contents of the fountain of knowledge onto the sponge. Some gets sopped up at random. Some runs away. Some drips out when the sponge wanders off. And much dries up and disappears (which allows room to sop up a little more later).

The final vision is of the student residing in a flowerpot. The educator pours knowledge into the pot. The student draws up what is needed to nurture growth and synthesizes it into wisdom. A good educator adds just the right amount of fertilizer to produce the maximum growth (I never did find out if this metaphor was referring to organic or inorganic fertilizer, but I suspect the difference in results would be minimal).[3]

There is a striking difference between the first two of these metaphors and the last. In the first two, the process is controlled by the educator and imposed upon the learner. In the third, the student-as-flower is provided with the nurturing educational elements and the educator empowers the growth of knowledge and wisdom within the student.

Alas, things are not quite that simple, but the different visions of the world of education represented by the flowerpot metaphor and the other two starkly illustrates the difference that I see between instructional systems and learning systems.

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3 One of the reasons I find this metaphor so compelling is that my wife owns a number of continuous process organic fertilizer factories in the guise of Appaloosa horses.

1.5 LEARNING SYSTEMS WITHIN EDUCATION

The term *learning systems* has surfaced recently to denote integrated student-centered learning environments.[4] A learning system differs from an instructional system in a fundamental way. The emphasis in many conventional educational programs has typically been more on the instruction than on the learner. The underlying assumption occasionally goes so far as to state that if only we can devise perfect instruction, any failure to learn is due to a faulty learner.[5] In contrast, the goal of learning system design is to provide student-centered educational experiences. The focus shifts from providing good instruction to fostering learning. Banathy[6] provides an example of a shift in the philosophical position and policies in education required to develop a system where the learning experience is the primary level and the learner is at the center. Banathy describes four types of instructional systems which range from institution centered (type A) through instruction centered (type C) to learner centered (type D). In his "Model D" instructional systems design "the learner is the key entity and occupies the nucleus of the systems space of education."[7] A learning system is a type D system.

How does a learning system relate to an instructional program? In my view, a learning system is a carefully designed, integrated educational environment that considers many factors that are sometimes neglected in the design of typical instructional programs. For example, many instructional programs are primarily content-centered, where the emphasis is on the presentation of content that is seen as important to the goals of the program. There is often little systematic concern with the characteristics of the particular learners, with the possibility of alternate delivery methods, with the possibility of customizing the program to suit the need of individual learners, or with the pursuit of excellence. Learning system design addresses these and other issues that combine to create a learning environment that is tailored to match the needs of the learners.

The image I used to hold of a learning system was a wall of pigeonholes, each containing a collection of instructional materials and a plan for conducting the learning experiences required for one unit of subject matter. The program for a particular situation would be created by selecting an appropriate array of materials from the pigeonholes. Thus, I saw a learning system dealing with a modularized array of learning experiences that can be mixed and matched to create a customized course for particular situations. The problem is in determining how large these pieces should be, in what order to sequence them, and especially how to integrate the ideas in each module into a cohesive whole.

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[4] See Hathaway, W. E. (1989). *Education and technology at the crossroads: Choosing a new direction.* Edmonton, AB: Planning and Policy Secretariat, Alberta Education; and Canadian Centre for Learning Systems. (1989). *Mission, goals, and programs.* Calgary, Alberta: Author.

[5] Engelmann, S., & Carnine, D. (1982). *Theory of instruction: Principles and applications.* New York: Irvington.

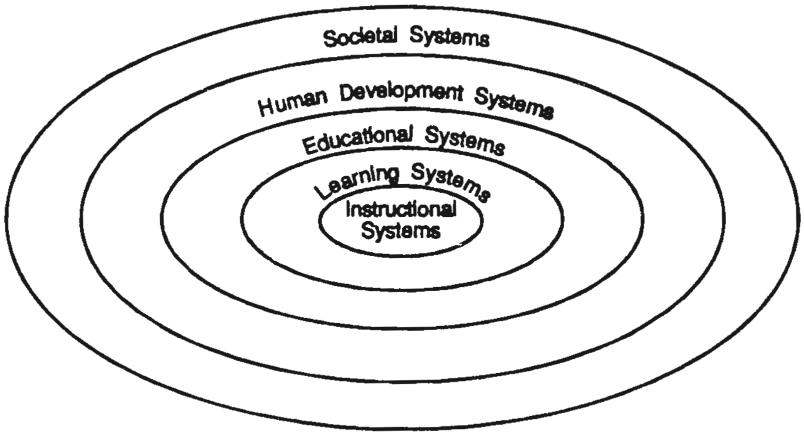
[6] Banathy, B. H. (1987). Instructional Systems Design. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 85-112). Hillsdale, NJ: Lawrence Erlbaum Associates.

[7] See, for instance, Banathy, *Systems Design*, (p. 103).

1.6 WHERE DOES A LEARNING SYSTEM FIT?

This book is about designing learning systems. For many years I thought it was about theory construction, but recently I discovered it was really a theoretical book about systems design.

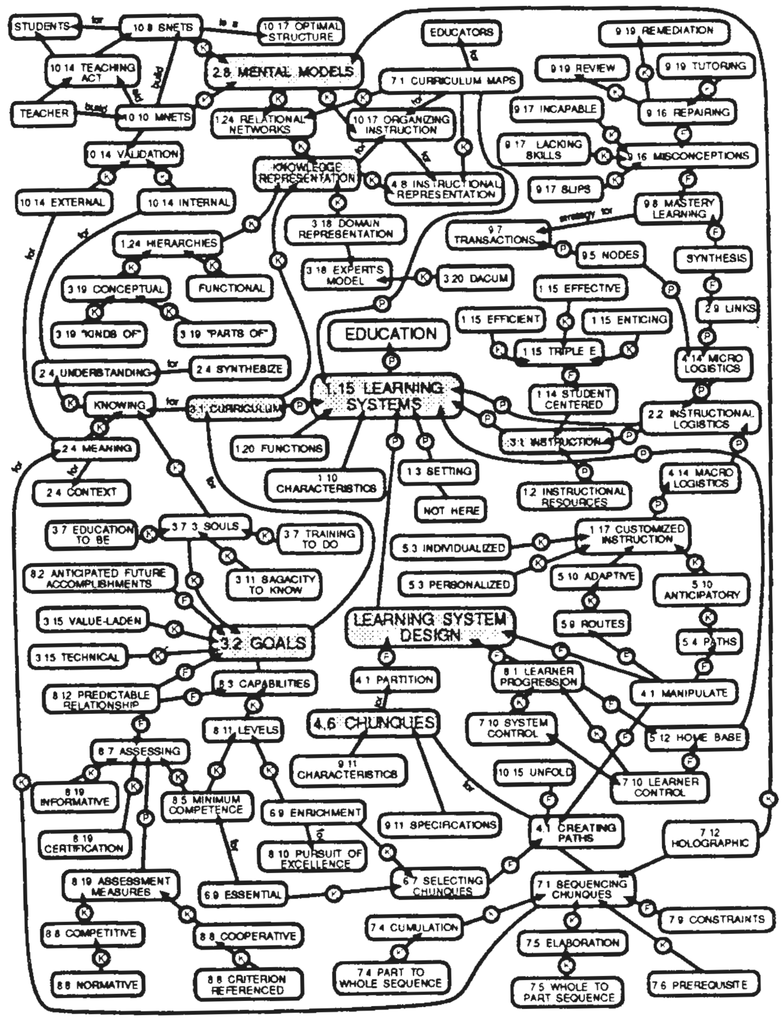
At a North Atlantic Treaty Organization workshop on educational reform our group of systems theorists and educational technologists tried to determine where instructional systems fit into the domains of human development and educational reform. We came up with what was humourously called the Bermuda Onion Model:



Within the broad scope of human development systems, educational systems can be viewed as formal systems like schools, colleges, technical institutes and universities. Learning systems are one part of (formal) educational systems, and consist in part of instructional systems. Learning systems are more comprehensive than instructional systems, as will be illustrated in the course of this book. But for now, learning systems can be described as larger than (superordinate to) instructional systems but smaller than (subordinate to) educational systems.

1.7 A MAP OF THE TERRAIN OF LEARNING SYSTEMS

This map (somewhat like a relational network) is one way of depicting a learning system. There is a larger copy on the last page (253) which you can pull out of the book. This map shows how many of the parts and functions of a learning system fit together.



This is how it works: Each of the boxes (nodes) represents an idea related to learning systems.[8] The text in the box matches text in this book, and the numbers (like 4.11) indicate the section in the book where the idea is first introduced. The lines between the boxes indicate that there is some sort of relationship between the ideas in the connected boxes. In a "conventional" relational network diagram, there would be text along each connecting line to indicate the nature of the links, and the direction of the relationship would be indicated by an arrowhead. Some links would consist of two lines, if there was a two-way relationship.

---

8 In a few cases, the boxes might appear to represent links, rather than nodes. In these cases, the text is in quotes.

1.8 REALITY STRIKES

It is really difficult to construct a network map like this, even with a computer, especially on a two dimensional piece of paper, so I have been obliged to take a few short cuts. Not many of the links have text. If there is no text, there is usually a letter in a circle. A "P" indicates a *parts-of* relationship, reading from the tail to the head of the arrow. For example, linking the two big shaded boxes near the middle, the relationship is read "LEARNING SYSTEMS DESIGN is a *part of* LEARNING SYSTEMS." Similarly, a "K" indicates a *kinds-of* relationship, as in the bottom right corner, prerequisite is a *kind of* sequence for Chunques.[9] Finally, an "F" indicates a *function-of* relationship.

A few of the links have text along them, but only in one direction. In the upper left corner the link between SNETS and STUDENT is read "SNETS are *for* STUDENTS." Again, the relationship is read from the tail to the head of the arrow. In any of these links, the reverse relationship has been left for you to deduce.

Links with no relationship stated indicate that there simply was not room to add in the text: this page takes over three hours to compile on my laserprinter.[10] The nature of these links can be discovered in the pages that follow.

There is an interesting relationship between this network and the layout of the book. The section reference numbers in many cases seem to hop all over the place. 1.17 connects to 4.14, 5.3, and 5.10. This is because the network is intended to *depict a knowledge domain*, while the book is organized with a different goal in mind: it is intended to *unfold the knowledge domain* in a manner that makes it easier for someone encountering it for the first time to understand it.

There are several paths you can follow in using this book. You can read the sections in the order in which I laid them out, which is the best sequence I could come up with to unfold my knowledge about learning systems design. You could also pick an interesting box from the network and start with that section, then follow a link to a connected section, and so on. Or you could choose one of the paths in the preface which list the sections which pertain to selected topics that I thought might be of interest to some readers. The path you choose will depend on your interests and, I suppose, on your learning style.

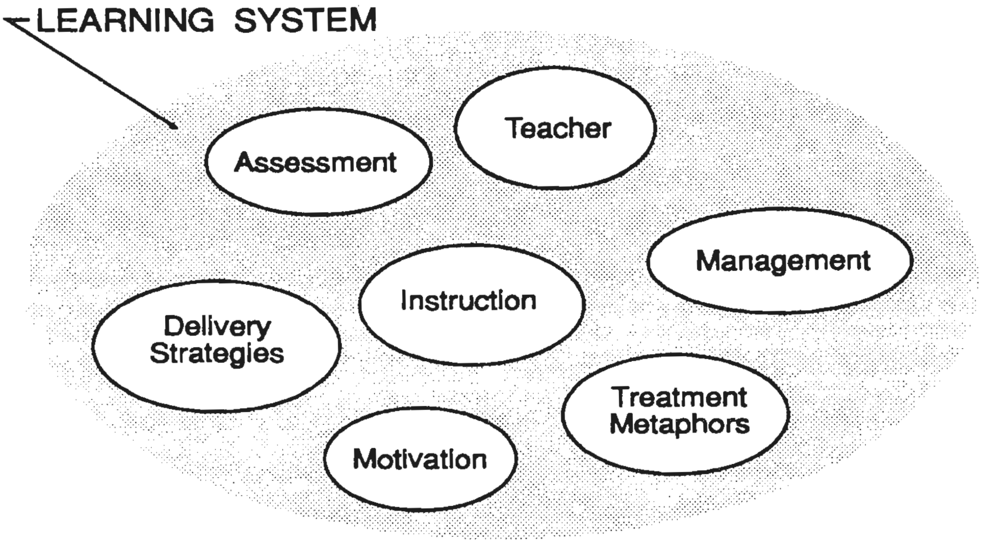
---

9 This is somewhat like the "is-a" term to denote a superordinate relationship which comes from a computer program for the Mac called SEMNET. It creates semantic network diagrams with the links defined by terms such as isa, hasa and so on. See also Denenberg, S. A. (1988). Semantic network design for courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 307-326). Hillsdale, NJ: Lawrence Erlbaum Associates.

10 As a matter of interest, this work was composed using Microsoft Word 5.0 on a Data General One laptop, formatted on an enormous 386 machine with 8 megabytes of memory using Word for Windows 1.01, and printed with an Adobe cartridge on an HP Laserjet II using Postscript. The figures were done using a remarkable drawing package, Coreldraw 2.0, and electronically pasted into the text. Some editing was done by Minsky (the cat, not the scholar) but I think I fixed most of it.

1.9 INSTRUCTION IS A SMALL PART

Instruction, if you think of it primarily in the sense of the *delivery of new material,* is a very small part of a learning system. Our chart suggests that a learning system consists of a number of components like the management things, the remediation things, assessment things, and the educational environment ... those kinds of things that sort of wrap around the delivery of instruction that make learning more effective. When I think about what a learning system is, I think that more than anything else it is the product of a *change in mindframe.* That mindframe has several critical attributes such as the primacy of the student, customized learning experiences, and needs centered curricula. The instruction itself might not be customized (as is implied by some individual instruction schemes), but other parts of the learning system are: such things as diagnostic testing and remediation (which must be individualized), or the relevance of examples,[11] and other factors of that nature. Here is a very rough diagram which illustrates how a learning system designer might view a system.



The delivery of instruction is only one component of the entire range of things that make up this system. Management is another. Learning systems design differs from instructional systems design in the management strategies that are used to guide the learners through the instruction: it is concerned more with the management part and the organizing part than with the instruction part. Usually, the instruction itself is very much like that proposed in conventional instructional systems design, applying many of the same strategy components and design models. By wrapping different management strategies around this instruction, I believe more effective learning environments can be devised.

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[11] The Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19* (6), 2-10.

1.10 MANAGEMENT STRATEGIES IN THE INSCITE PROGRAM

One problem with designing the INSCITE program became immediately apparent when the students arrived. How could two instructors manage the activities of a combined class of forty or so students, all doing different things at the same time? A management scheme was essential to keep all of these different activities by all of these students running smoothly. We first implemented some rather obvious things.

Students recorded their own attendance by signing in and out each day in a registration book. Each student was assigned as foreman for one lab station, inventorying the equipment at the start and end of each class, making sure the students who used the area cleaned it up, checking the supply situation, and providing peer tutoring for students who selected that work station for study. One *special projects*[12] student acted as class superintendent, learning junior management skills and supervising the foremen. The supervisor also acted as the second level of peer tutor for the students. These methods took care of some of the administrative details, and gave the students some real responsibility in operating the labs.

It was essential that each learning module was a self contained learning experience that did not depend on other modules for prerequisite knowledge. We thought at first that this might prove to be impossible, but in the end, we found that many things that are presumed to have some required sequence really do not.[13] The students kept track of which learning modules they had completed on a chart in the front of their notebooks, and on a large wall chart they indicated which one they were currently working on. This let the instructors know who was doing what. Because the students had to periodically have the instructors sign off on the embedded questions, we knew how they were progressing.

We were worried about fragmentation. By splitting up the subject matter into independent and self contained modules, we worried that connections between them would be lost, and the students would miss the bigger picture. As one possible solution, we even reorganized the physical layout of the labs. The student lab stations were not clustered together into similar areas like woodworking or photography. Instead, we mixed them all up (the lab stations, not the students) so that the student exploring photogrammetry was next to another working with a milling machine. We believed that a cross fertilization of understanding might be encouraged by the close proximity of these different processes. All of the students completed a pre-test and post-test of general knowledge about the various lab processes each year, so that we could determine if our assumption was valid. This data was collected for thirteen years. It was all thrown out while I was on sabbatical in Utah: there went my nice tight empirical dissertation research.

---

12 These special projects students were enrolled in contract-based independent study courses to explore ideas not in the regular curriculum.

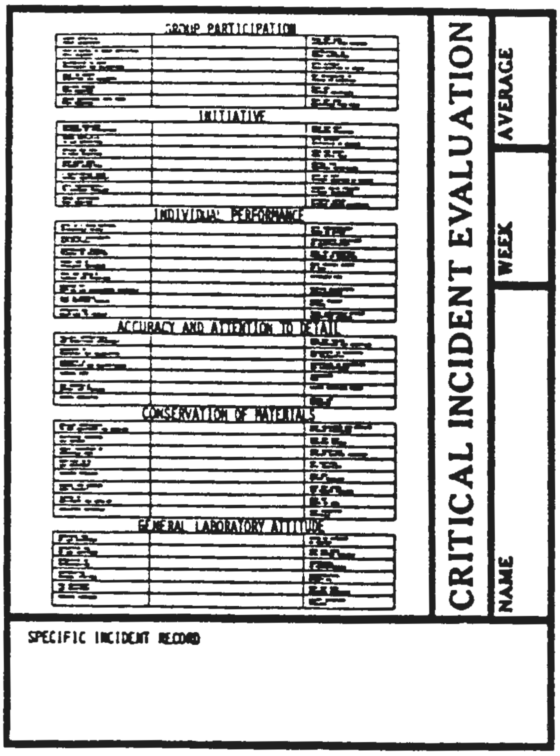
13 See Bloom, B. S. (1976). *Human characteristics and school learning.* New York: McGraw-Hill.

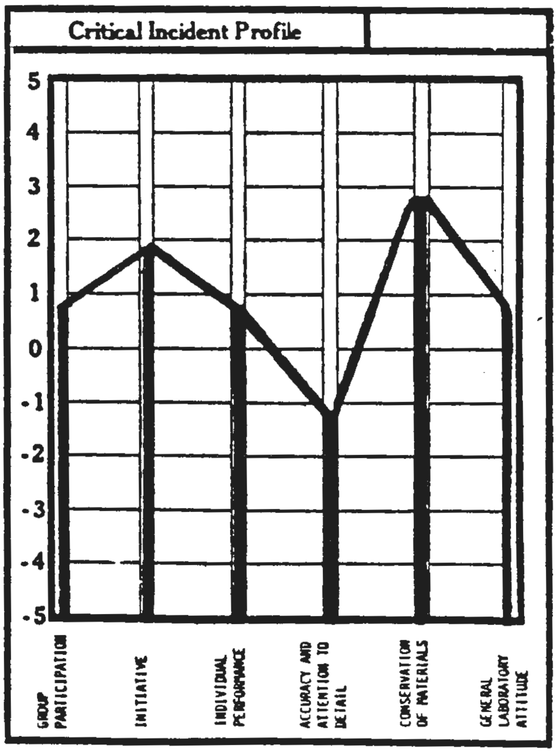
1.11 ASSESSMENT OF EXCELLENCE

Fragmentation problems remained a thorny issue. We felt that there was not a single item of content that was defensible in the sense that, if students did not master it, they should fail the course. It was not the *particular items of content* that were important, but rather broad and meaningful understandings of the nature of the processes, how they worked, why they were important, and so on. The goals of the program stressed these interrelationships between technologies and their importance in a technological society, so we were compelled to design an assessment system which would address these issues.

We developed a common evaluation sheet that the students did at the completion of each learning module. This test always asked the same questions: How does the process work?, How does it relate to industry?, Why is it important?, What other processes are similar?, What are the variables?, What values did you use for these variables? We also asked the students to evaluate their results and predict what they could do to improve the process. We felt that because the students always knew in advance what they were looking for, and because these things were common across all of the processes they were exploring, we could encourage them to discover more global relationships. The assessment measures fostered broad understanding.

These tests were evaluated on a critical incident sheet which had a list of about fifty directly observable incidents that we believed were critical in determining the likelihood that a student would be successful in an technical laboratory environment (such as the student labs). The items covered attitudes, aptitudes, knowledge, and skills.





1.12 THE BEGINNINGS OF CHUNQUE-BASED SYSTEMS

Over the last six years, I have been exploring how the management strategies that formed the basis of the INSCITE program could be tied to current thought on instructional theory, and how they could be broadened to include prescriptions for the management of large scale curriculum projects. Through a fortunate coincidence, as a part of the internship for my doctoral studies I was assigned as the project director for the implementation of a very large Adult Basic Education program called PASSPORT to be delivered to over twenty thousand adult education students at four institutions and more than fifty outreach sites across Alberta. At The Canadian Centre for Learning Systems Janet McCracken and I developed an instructional logistics scheme to manage this project for delivery through conventional classes, outreach centers, computer managed learning, and distance education. This implementation incorporates many learning system design prescriptions, and is used as an example throughout this book.

The proof of the pudding, they say, is in the eating. These learning system propositions are now being used to guide the implementation of a modified competency-based education approach to programs at Lakeland College in Northeastern Alberta and Northwestern Saskatchewan.

So, this book is about learning systems. A learning system is a comprehensive, systematically designed, student-centered educational environment. It consists of three parts; a collection of self-contained modules, a curriculum map which illustrates their relationships, and a management scheme to guide the students through the modules. It is a bunch of goals and principles that stress the primacy of the student, and it is a way, I suspect, of making education what it could be and should be ... which in many instances it now is not. But most of all, learning system design is guided by a different mind frame that stresses the accomplishments of individual students and the interrelationships between the notions that make up the curriculum.

1.13 CHARACTERISTICS OF A LEARNING SYSTEM

There are a number of basic assumptions about the design of student-centered learning systems that illustrate the difference between instructional systems and learning systems. Learning systems are based on a few fundamental premises:

> Instead of designing cohort-based learning experiences for a heterogeneous group of students, learning system design emphasizes providing customized instruction to assist each student to achieve at least the minimum capabilities required for each notion in the curriculum.
>
> Instead of beginning with a scholar's domain knowledge and developing a course around it, learning system design starts with *stakeholders' needs* to design a system to deliver knowledge in a form that fills those needs.[14]
>
> Instead of beginning with a list of facts to be recalled, learning system design begins with a network of ideas, skills, and interrelationships that form a cohesive mental model of capabilities and accomplishments.
>
> Instead of viewing the instructor as a deliverer of content, learning system design promotes the role of faculty as educator of students. Faculty responsibility shifts from the presentation of material to the mentoring of students to help them achieve the goals of the curriculum.
>
> Instead of designing one path for all students, learning system design begins with the premise that different students require different learning experiences, so customized paths through the curriculum must be created for each student.

Over the next few sections each of these premises will be explored in more depth.

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14 Stakeholders in this sense include the students, parents, employers, and any other interest groups who have a stake in the outcome of the program. The point is that the nature of the program is determined by these outside individuals and groups, not by the educators themselves.

1.14 FROM TEACHING ALL TO TEACHING EACH

The vision that many educators have about the teaching act is a metaphor which revolves about the notion of presenting their knowledge to their classes. The focus of responsibility is centered on preparing lecture notes which contain a well organized sequence of ideas which represent their domain. The student bears the responsibility for learning while the instructor bears the responsibility for exposing knowledge. Those students who are fortunate enough to learn a fair proportion of this knowledge pass the course. Those that do not, do not. This vision looks suspiciously like the student-as-sponge metaphor.

This has also been referred to as the "pass the best and flunk the rest" metaphor. Merrill calls it a "spray and pray" strategy.[15] I do not believe this is quite good enough.

My boss, the senior academic officer at our college, suggests that we need a new metaphor. He views it as a shift from teaching *all* to teaching *each*. This implies that the burden of responsibility shifts partly from the student to the teacher. The teacher, in addition to (or sometimes, instead of) being a presenter of knowledge, becomes a mentor to each student, charged with the responsibility to assist each student to achieve at least the minimum capabilities necessary to master the course.

This is a simple notion. It is in some ways an example of one of Kuhn's paradigms, a whole new way of looking at things.[16] But it encompasses a somewhat different notion as well. It is more than a model or paradigm of what it is to teach. It is indeed a whole new way of looking at things. It encompasses the new mindframe I spoke of earlier. The student becomes the center of the educational universe. Each student.

Learning systems, as I propose them here, demand this mindframe of the educators involved in their design and delivery. Learning systems have no room for spray and pray metaphors or tipped head students with funnels in their ears.

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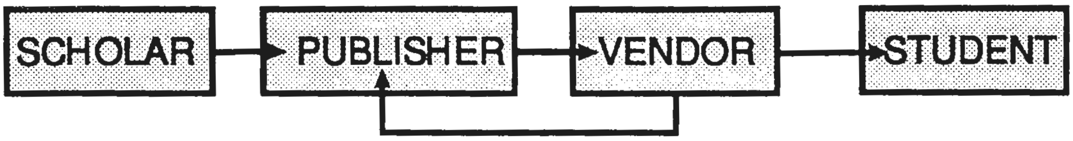
15 Merrill uses this metaphor in many of the talks he gives regarding his "Second Generation Instructional Design" propositions. See Merrill, M. D., Li, Z., & Jones, M. K. (1990). Limitations of first generation instructional design. *Educational Technology, 30* (1), 7-11.

16 Kuhn, T. S. (1970). *The structure of scientific revolutions.* (2nd ed.). Chicago: University of Chicago Press.

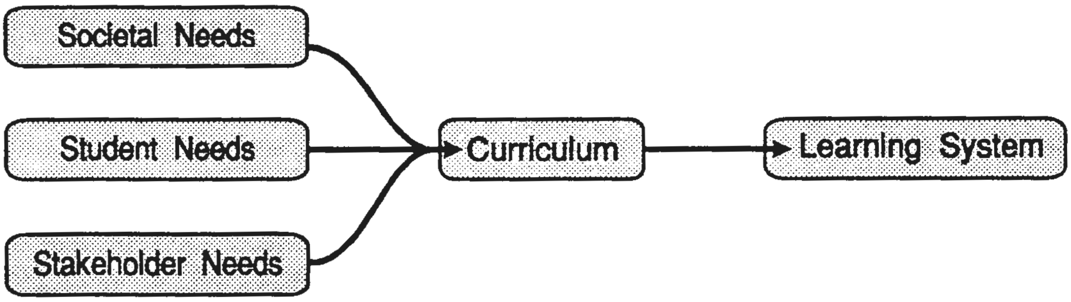
1.15 FROM DOMAIN CENTERED CURRICULUM TO NEEDS CENTERED CURRICULUM

Branson and Grow[17] point out the traditional methodology for developing scholarly books (like this one) is to have a domain expert (a scholar) author a text which is then reviewed and edited by a book publisher and presented to a vendor who attempts to sell it to teachers. The resulting book, if it is any good, eventually finds its way into the classrooms of formal education. The teachers who use it provide a feedback loop to the publisher which results in changes. A commercially produced textbook follows a similar development cycle, where the scholar passes the work on to a professional textbook writer who is employed by a publisher, and so on. The feedback loop remains basically the same.



Curriculum designers and teachers tend to develop courses based on the textbook, often following the topics and chapters, modifying a bit here, deleting a bit there, and adding a bit based on their own expertise. The curriculum of a course becomes centered on the text. This is one example of *domain centered curriculum.*

Learning systems design proposes that this model be replaced by a model centered on needs; the needs of the student or the needs of an occupation or profession or of society.



Instead of beginning with a scholar's knowledge of a domain and developing a course around it, learning systems design starts with a broad range of stakeholder's needs to design a system to deliver instruction in a form that fills those needs. This is needs centered curriculum development. We will look at course design following these notions more closely in Part Three, Representing a Curriculum.

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17 Branson, R. K., and Grow, G. (1987). Instructional systems development. In R. M. Gagne (Ed.), *Instructional technology: Foundations.* Hillsdale, NJ: Lawrence Erlbaum Associates.

1.16 FROM EMPHASIS ON FACTS TO FOCUS ON INTERRELATIONSHIPS

How often, in your experience, have the overwhelming proportion of assessment measures in a course been based on having the student memorize and recite facts or summarize facts extracted from some work? Bloom recognized this problem in 1976. He notes:

> ...learning tasks in which the burden of remembering terms and definitions in the tasks was unusually great. In a single chapter in widely used textbooks we found as many as 100 to 150 new terms introduced and defined ... we found that up to 80 percent of the terms were used only on the page in which they were introduced - and never again used in the course ... we may question the value of burdening the students with a terminology that even the author of the textbook doesn't find useful. ... That students should learn such material may be questioned from the viewpoint of its utility, its meaningfulness, and the likelihood of long-term retention.[18]

It would appear that throughout the formal educational system which predominates in our culture, the emphasis is on fragmented bits and pieces of knowledge, each studied in some depth and in significant isolation from other realms of understanding. The meaning of each piece is often lost in the struggle to remember and recall primarily factual knowledge about these many bits. Learning systems design proposes that instead of beginning with a list of facts to be recalled, we start with a network of ideas, skills, and interrelationships that form a mental model of the reality that we want our students to understand.[19]

The pervasive mindframe which characterizes learning systems design draws heavily on the notion of the meaningful understandings which can result from a more integrated study of many ideas and the ways in which each relates to the others. I will return at length to the application of mental models to the design of learning experiences. It is central to this vision.

This emphasis on integration is one of the things the evaluation scheme in the INSCITE program encouraged. Common questions were asked, regardless of the content the students explored. Many of the questions were open ended rather than specific, and said in effect, "find a principle" when the students were asked to "explain what happened, and predict what can be done to change it."

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18 Bloom, *Human Characteristics,* (p. 25).

19 Shuell's work on learning phases suggests that the emphasis on what naive students learn as they progress through instruction shifts from facts and isolated bits of knowledge to more global perspectives. Learning systems design as proposed here speculates that it might be profitable to alter the initial instruction in a domain to counter this tendency, and suggests that the learning phases may be more of an artifact of the educational system and the way learning experiences are structured than a characteristic of the way people learn. See Shuell, T. J. (1990). Phases of meaningful learning. *Review of Educational Research, 60* (4). 531-547.

1.17 STUDENT CENTERED LEARNING EXPERIENCES

Earlier, I mentioned the idea of the student becoming the center of the educational universe. Bloom states that in our educational system "much of the teaching and learning is group based and teacher paced,"[20] and,

> ... schools by and large expect the student to accommodate to the instructional characteristics of the teacher and the learning material selected by or for the student ... he must adjust to the instructional properties and characteristics of the material and the teacher.[21]

What I am proposing is that we grab the other end of the stick. To develop Banathy's[22] student-centered type D instructional systems and accommodate Bloom's criticism of the conventional learning environment, we must create learning systems where the system adapts to meet the needs (both motivational and instructional) of the particular student. This is what I mean by a student-centered learning system. Good instruction, according to Charles Reigeluth,[23] must be efficient, effective, and appealing. Glenn Snelbecker refers to this as efficient, effective and enticing instruction. I refer to this notion as the *Triple E*. Reigeluth defines these as:

> The *effectiveness* of the instruction, which is usually measured by the level of student achievement of various kinds.
>
> The *efficiency* of the instruction, which is usually measured by the effectiveness divided by student time and/or by the cost of the instruction (e.g., teacher time, design and development expenses, etc.), and
>
> The *appeal* of the instruction, which is often measured by the tendency of students to want to continue to learn.[24]

In the design of many instructional systems, not all of these three aspects of design are considered, but they should be. Also, we should consider whether the measure of success on these three scales should be group success or individual success. Should a program be judged more successful if it produces a few very superlative graduates or if it produces a great number of adequate ones? I do not propose to have an answer for this, but it seems that the more global the perspective from which this issue is viewed, the more difficult the choice becomes. Societal concerns seem to vacillate between one view and the other. On one hand, society seems to demand a general improvement in effectiveness across the board in public education. On the other, society decries our lack of success in producing leading scholars and scientists. There is a trade off between allocating resources for the gifted few or for the entire population.

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20 Bloom, *Human Characteristics*, (p. 20).

21 Bloom, *Human Characteristics*, (p. 21).

22 Banathy, *Systems design.*

23 Reigeluth discusses his version of the Triple E in Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates. See also Snelbecker, G. E. (1985). *Learning theory, instructional theory, and psychoeducational design.* New York: University Press of America.

1.18 THE TRIPLE E IN LEARNING SYSTEMS DESIGN

There is another way of looking at the need for efficient, effective, and enticing instruction. What is the context of each of these: to what do they refer? Is the instruction effective for the learner? Is it efficient for the learner or the institution? Is it appealing to the faculty or the student? A fundamental proposition here is that in the design of a learning system, the interests of the learner must be considered first. Let's look a little more closely at this proposition. The Triple E can refer to the learner, the faculty, the institution, or any number of other stakeholders. If we construct a matrix of some of these elements, the perspective of each group can be explored:

	LEARNER	FACULTY	INSTITUTION
EFFICIENCY	Time	Workload	Dollars
EFFECTIVENESS	Grades	Contented Students	No Hassles
APPEAL	Relevant, Interesting	Good Students	Prestige, Turf, Dollars

The particular data in each cell of this matrix is questionable, of course, but illustrates the point that the Triple E shows considerable variance depending on the perspective from which it is viewed. For a learner, the triple E might be expected to be optimized by good grades in relevant, interesting courses with the potential for career advancement, in the shortest possible time. In contrast, for the institution, optimizing the triple E might entail curricula and students who enhanced institutional prestige across it's selected turf with no hassles at the minimal cost. For faculty, it might be good, happy students achieving good grades, combined with a low work load.

I am proposing here that we must optimize the triple E from the perspective of the learner. Learner considerations must predominate in the design of learning systems, and it is not only the instruction, but the whole learning environment that must be optimized in this fashion. The implications of these learning system prescriptions include a need to accommodate the needs of society, the institution, and the faculty to the requirements of a triple E student centered learning system ... but the learner must still come first. In the design of a learning system, careful consideration must be given throughout the process to the implications of design decisions to each cell in the triple E matrix.[25]

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24 Reigeluth, *Instructional Design, What is it,* (p. 20).

25 In considering the triple E and its relationship to this matrix, on a more global level the horizontal axis might be expanded to include a wider range of stakeholders, such as the public, the potential employers of the students, and so on. The Chunque Theory does not address these issues, as they lie more in the domain of the value laden curriculum and in needs assessment theory. See Banathy, *Systems design*. Instructional technology: Foundations. Hillsdale, N J: Lawrence Erlbaum Associates for a discussion of these aspects of curriculum design.

1.19 AN EXAMPLE: PASSPORT LEARNING SYSTEM

In 1987, the four Alberta Vocational Centres[26] decided to implement a comprehensive adult basic education program across the province of Alberta. This program is comprised of ninety nine units of content ranging from basic math skill to effective parenting. Each unit has approximately ten major objectives, resulting in about one thousand discrete competencies. The program is to be delivered at the four institutions, approximately fifty outreach sites, a number of gaols, and by distance delivery to individuals spread across the province. Delivery systems include traditional instructor led classes, computer managed learning, paper based independent study, and delivery by modem to home terminals. There is a requirement for common competency based assessment across the numerous sites and delivery modes, and provincially accredited certification for each unit of content.

During the development of an instructional management system to implement this program, a number of questions arose regarding implementation strategies. These included how to determine the scope of a unit suitable for certification, a definition of the characteristics of independent study units, how to determine optimal sequences of progression though modules that are basically independent but still interrelated, how to devise assessment measures that can be used to control certification, and so forth.

The basic design of the learning system entailed the creation of a number of different paths through the units of content, based on the needs of the learners. This required that each unit of content could stand alone as a self contained module, and that a management system be devised to route the learners through the different modules. The concept of a home base, or central scheduling module, was included to provide a comfortable base from which a learner could strike out in different directions to explore appropriate learning experiences. A major problem was anticipated, however, as the learners would quite often be unaware of the nature of the learning opportunities available to them, or of the significance of these opportunities, until they had been involved with the program for some time. As a result, the nature of the paths that learners follow must be devised on-the-fly.

During the course of tackling these and other intractable problems, it was decided that a comprehensive theoretical knowledge base would have to be assembled to inform the design and implementation decisions that arose in developing the program. At the Canadian Centre for Learning Systems we began an in-depth investigation of the problems related to this task, which resulted in the propositions of Chunque-based learning systems.

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26 The Alberta Vocational Centres (now called colleges) are provincially administered adult upgrading institutions mandated to provide remedial and prevocational opportunities to disadvantaged Albertans. Two are urban, two are rural.

1.20 MULTIPLE PATHS

In designing the PASSPORT learning system one of the major concerns was the design of different paths through the modules that would address the needs of particular students, much as Bloom[27] suggests. We used to talk about how a new student would encounter the program for the first time. Imagine a couple of fellows sitting in the bar talking about dwindling job prospects. One asks the other for help filling out an application form. It turns out that he cannot read or write very well, and the application form is a major roadblock to getting a job. His buddy tells him about the PASSPORT program at the local outreach center and how it can help him learn to read.

Now, the problem is that the PASSPORT program covers everything from basic literacy to interpersonal skills to financial management, or as we used to say, "from don't drop the baby to balancing the budget." This prospective student has a very particular need at this time: he only wants to be able to fill out application forms. PASSPORT can provide assistance in this as well as a host of other life skills that might be of interest to him, but he probably does not know they exist.

How does the system guide this student along a path through an appropriate sequence of learning experiences? Let's continue to assume for a moment that the student has this very specific goal in mind: his intention is only to learn how to read and write well enough to fill out application forms and so forth. To support this intention, the path should be narrow and deep, focussing in on only those competencies that will address his goal.

But I believe the system has an obligation to help the student realize the broad array of other life skills modules that are available through the program. To do this, perhaps a skim across many of the kinds of modules would be appropriate: a broad and very shallow path. How do we decide? Or does the student decide? How can the student decide if he doesn't know what is available? Tough questions.

Merrill talks about the same kind of problems with different paths through the instruction for different kinds of goals in his ID Expert.[28] He gives the example in technical training of different paths for repair technicians, supervisors of those technicians, or consumers of the equipment. They all have needs for different competencies which require different paths through a collection of learning experiences based on their intentions. Learning system designers are constantly faced with these kinds of questions. Instructional logistics strategies for the management of student progress through a collection of learning experiences can provide some answers if the learning experiences and the system within which they reside are constructed in an appropriate way.

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[27] Bloom, *Human Characteristics.*

[28] Merrill, M. D. (1988). An expert system for instructional design. *IEEE expert*, Summer, 25-37.

1.21 REFLECTIONS ON JUST WHAT IS A LEARNING SYSTEM

As we developed the INSCITE program, we often took the time to sit back and reflect, in a global way, how all of the different elements of the program fit together into a cohesive whole. Over the years, we adjusted, modified, and fine tuned the system so that the various pieces worked well together. I call this a *learning system.* I view a learning system as an integrated and comprehensive learning management and delivery system designed to maximize the benefit of the educational experiences for *the learner.* It is a student-centered way of organizing the resources of an educational system in a manner that addresses the needs of individual learners. It is a management structure that recognizes and promotes the need to optimize both the humanistic contribution of the teacher and the systematic contribution of technology.

A learning system is more formally defined as:

A collection of instructional and management strategies, techniques, tools, and materials that are combined to create an educational environment with optimal customized paths for each student through a collection of learning experiences.[29]

Related to this definition is the distinction between an instructional system and a learning system. In the past, educators often assumed that students incorporate new knowledge into their minds in much the same form that it is presented, like in the funnel metaphor; that the teacher can package the ideas and pour them in a student's ear. Under this assumption, instruction can be imposed upon the student. All that is necessary is a one-way communication of knowledge, a teacher centered and content centered activity. Recent conceptualizations of how our minds work[30] propose that the learner transforms newly encountered knowledge into a personalized model that relates and conforms to preexisting knowledge structures and experiences. Under this assumption, learning systems should provide a two way communication[31] or dialog between the instruction and the learner to detect the individual qualities of the student and the interpretation that the student puts onto the content. This learner-centered approach is aimed at providing a better match between the goals of the curriculum and the existing knowledge structures of each learner.

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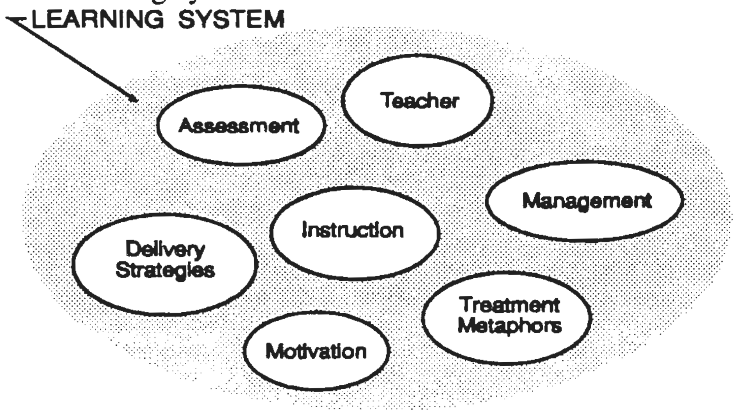
29 For a definition of learning experience see Tyler R. W. (1950). *Basic principles of curriculum and instruction.* Chicago: University of Chicago Press. (p. 41).

30 Marvin Minsky, in his wonderful book, *The society of mind* explores a model of the mind that assumes this kind of integration of new ideas with pre-existing experiences. The ideas in this book form the foundation of the conception of mental models underlying the assumption of the Chunque Theory. See Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster.

31 Alex Romizowski and David Merrill have both developed models of instruction based on interactive dialogues; Michael DeBloois stresses the crucial importance of these ideas throughout his work on interactive videodisc design. See Merrill, *An expert system.* DeBloois' comments are from personal conversations during 1984 and 1985 in Logan, Utah.

1.22 INDIVIDUALIZED INSTRUCTION

One of the concerns that always comes up when we talk about the many learning systems propositions discussed in the last few pages is individualized instruction. Earlier, I mentioned that the actual delivery of instruction was but one small part of a total learning system. I used this chart to show some of the other parts:



When we talk about individualized instruction, many educators think about independent instruction schemes that are student-paced and based on independent study manuals. What is proposed here is quite different. Learning systems design does not imply that each student is provided with a self study manual or other independent study resources. When I propose student-centered customized paths through a series of learning experiences, I am suggesting that *some parts* of the learning experience be tailored to individual learners. For example, remediation must be based on the particular misconceptions held by individual students. Remediation *means* correcting particular misconceptions which must be identified in *each* learner. Another example is allowing students to select certain modules to make up a program to suit their needs. This does not imply that each student studies these modules on their own, only that they have the opportunity to select from a range of options. This is quite common at the program level where students can select courses. Learning system strategies propose using the same techniques at the course level.

Benjamin Bloom[32] encountered this same problem in his learning for mastery proposals. He has repeatedly pointed out that mastery learning is based on group instruction followed by individual assessment of mastery and remediation for particular students. His article *The Two Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring* makes this clear. What he proposes is a shift from teacher-paced and teacher-based instruction to student centered learning environments where the determination of what to do and when to do it is based on analysis of student accomplishments and diagnosis of student difficulties. Learning system design proposes that when it is necessary the instructional system is adapted to suit particular learners rather than expecting the learners to adapt to the system. A radical thought, perhaps, but an effective mindframe.

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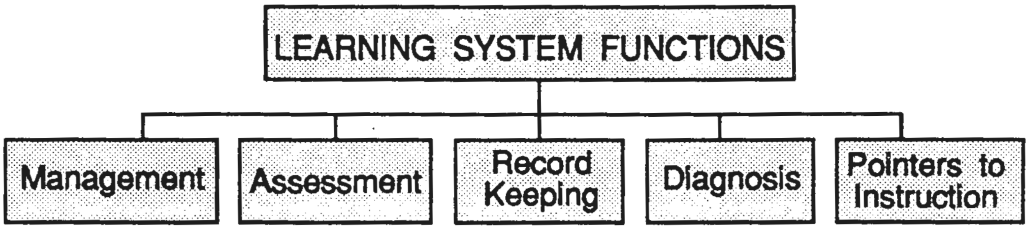
32 Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13* (6), 4-16.

1.23 LEARNING SYSTEM FUNCTIONS

What does a learning system do? The answer to that question depends in part on the sophistication of the system. With the availability of powerful computer based instructional systems, it is now possible, in a practical sense, to implement instructional management strategies that can perform functions that would have been difficult if not impossible in previous times. A fundamental premise of learning system theory is that one should investigate the widest possible range of functions that would provide optimal learning experiences for each student, and then select those that make sense in a practical situation. Computer managed learning promises to provide many opportunities to automate a wide range of administrative and record-keeping functions that will free up educators to focus on learning problems and strategies that computers cannot address. In support of the functions provided by conventional instructional systems, a learning system can in addition provide extensions to functions like those listed below.

Regardless of whether computer based or entirely teacher based, a learning system performs five major functions in addition to the actual delivery of instruction: management, assessment, record keeping, diagnosis, and pointers to instructional resources.

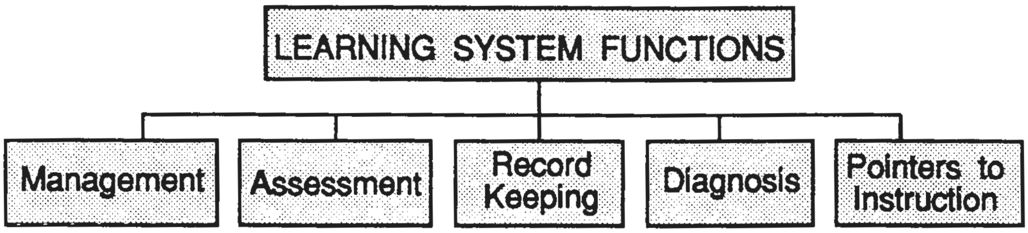


The *management* function is concerned with guiding the student through the learning experiences in an optimal fashion. This is the major focus of this book.

The *assessment* of student performance throughout the learning process provides critical information that can be used to determine what the student should do next. If appropriate assessment is embedded throughout the learning process, decisions can be based on actual data about the progress of the student instead of on *assumptions* about the student. This is essential in the design of student-centered learning systems, and will be explored in depth in Part Eight, Assessment and the Pursuit of Excellence.

1.24 MORE FUNCTIONS

Closely related to assessment is *diagnosis*. While assessment implies collecting information about student performance, diagnosis is the use of that information to determine the reasons for less than optimal performance and what steps should be taken in light of those discoveries. Diagnosis has been split off from assessment into its own box primarily to ensure that it does not fall between the cracks. A shortcoming of many assessment systems, especially in computer managed learning systems, is the lack of a link between the assessment of student performance and the use of this information in decision making. While assessment is discussed in Part Eight, the use of diagnostic information from assessment is explored in Part Nine, Micro-Logistics Strategies.



Record keeping is a crucial function of a learning system as the strategies proposed here require the use of a considerable body of data to design the best possible path for each student. Back in the sixties, we spent a lot of time figuring out how to keep and access student records for the INSCITE program. Fortunately, record keeping is a much simpler matter now than it was before the availability of microcomputers. Unfortunately, may computer managed learning systems keep the wrong records and generate reams of data that are useless to inform our instructional logistics decisions.[33] Record keeping is not addressed to any great extent in this book.

Many computer managed learning systems do not address the actual delivery of instruction, but provide prescriptions for to the student and *pointers* to the next appropriate piece of instruction. The learning systems we will explore here prescribe very definite specifications for what the instructional resources must include in terms of management and assessment characteristics, but do not address issues concerning the design of the instruction itself. A comprehensive examination of learning systems must also include the optimal kinds of *delivery systems* that must be available to present this instruction, but, once again, the design of those presentations is beyond the scope of this work.

Many instructional systems functions are represented in the Chart from the Canadian Centre for Learning Systems presented in Section 1.2.

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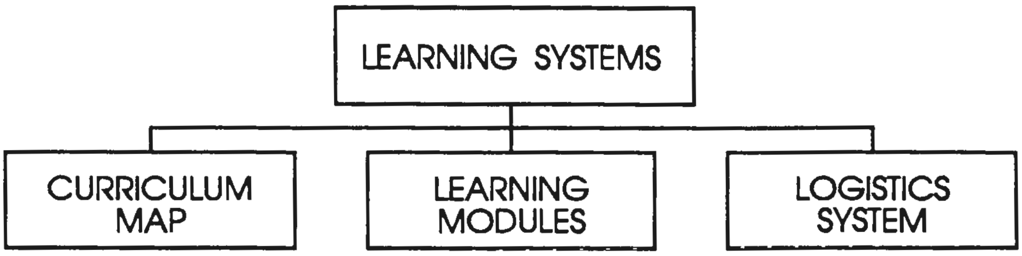
33 Bloom discusses the difficulties of determining what is happening with particular students and why it is happening in the first chapters of *Human Characteristics and School Learning*, cited earlier. This book provides great insights into the problems of developing student-centered learning experiences and the mindframe of traditional educators.

1.25 THE THREE PARTS OF A LEARNING SYSTEM

Now that we have defined, both informally and formally, what a learning system is, and what it must do, the question arises, "What does it look like? What is it made of?" A learning system is comprised of three parts: a curriculum map (which defines the content), a collection of learning modules (instructional resources), and a logistics system that manages student progress through the modules. These three parts provide a description of the ideas to be included in the curriculum, a set of learning experiences for the students, and a management system to guide the progress of the student through the curriculum.



Many typical courses in public education and training do not qualify as learning systems for any one of a number of reasons. The most significant is that many courses only have one possible path through the curriculum that does not consider either the instructional needs or desires of any particular student. This one path is usually an average student path, but is occasionally a lowest common denominator path. Other courses or programs are not learner centered, based on the qualities of the students, but teacher centered, where the teacher is considered the fountain of knowledge, charged with the responsibility of delivering a fixed and rigid curriculum despite the characteristics of the students or the situation.

To qualify as a learning system, a program must exhibit these essential characteristics:

The curriculum must be partitioned into meaningful self contained pieces (aha! That must be a Chunque!).

The pieces must be manipulated to create a customized path through the learning experiences for each learner.

Review and remediation tailored to particular students must be provided throughout the program.

The emphasis must be on encouraging each student to master each piece of content before progressing to the next.

Assessment must be criterion referenced, not normative.

1.26 THE COMMUNION OF MAN AND TECHNOLOGY

For the propositions of a complex learning system to gain acceptance, they should provide self-evident potential to improve at least one of Reigeluth's three characteristics; efficiency, effectiveness, or appeal. While we stressed that these improvements should be centered on the learner, the development of learning systems also permits improvements in the efficiency, effectiveness, and appeal of the instructor. In particular, the capabilities of technologically enhanced learning systems hold the promise of a "right tool for the right job" perspective in providing instruction and managing the learning environment.[34] The teacher can do what humans do best, and the system can assist by doing what machines do best.

Of course, problems arise when either one of these elements is missing. A totally technological learning system can certainly be efficient, effective, and appealing, but optimally there has to be a human resource available to the learner when the machine cannot understand the learner. And it seems important to point out to the learner that it is almost always the machine that has failed, not the student.[35]

The implementation of learning systems does not require technological support through the use of computers or mediated instruction. Competent teachers use many of these strategies "on-the fly" in their classrooms. However, one of the most difficult to implement in a classroom is the creation of an optimal set of learning experiences tailored specifically for each student. Teachers attempt to provide customized instruction for particular students through activities such as individual work with students or tutoring sessions outside of regular class hours, but these are complex and time consuming activities. With the availability of computers in educational institutions, however, the possibilities of combining the strengths of technology and the teacher promise advances in the presentation of instruction and the management of learning that would be difficult to achieve by either the teacher or the machine acting alone.

One of our main goals at The Canadian Centre for Learning Systems was to define excellence in education. Quality Education has long been a buzz word in the educational community, but adequate definitions of *quality* are hard to find. We looked at the work of Robert Persig[36] for the basis of a conceptualization of excellence. He defines *Quality* as excellence residing in things, and *Caring* as excellence residing in people. An excellent learning system, then, must combine quality instructional resources with caring educators, to provide the best of both. We call this a communion between humans and technology. It really means using the right tool for the right job. The trick is to find the right balance. To create a communion between the man and the machine. Or put more gently, the communion between humans and technology.

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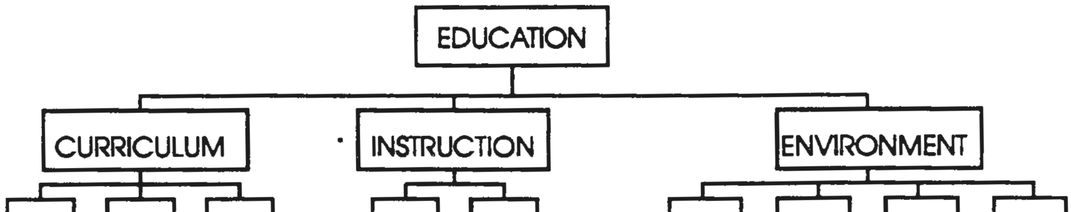
34 See Hathaway, *Crossroads*.

35 This topic is discussed in depth from a computer application perspective throughout Norman, D. A., & Draper, S. W. (Eds.). (1986). *User centered systems design: New perspectives on human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

36 Persig subtitles his book "An inquiry into values". *Zen* provides a provocative look into the differences between the romantic and classical appearances of the world, and Persig's attempts to define Quality, and find a common ground between the technocrat and the artiste. See Persig, R. M. (1984). *Zen and the art of motorcycle maintenance* (2nd ed.). New York: Morrow.

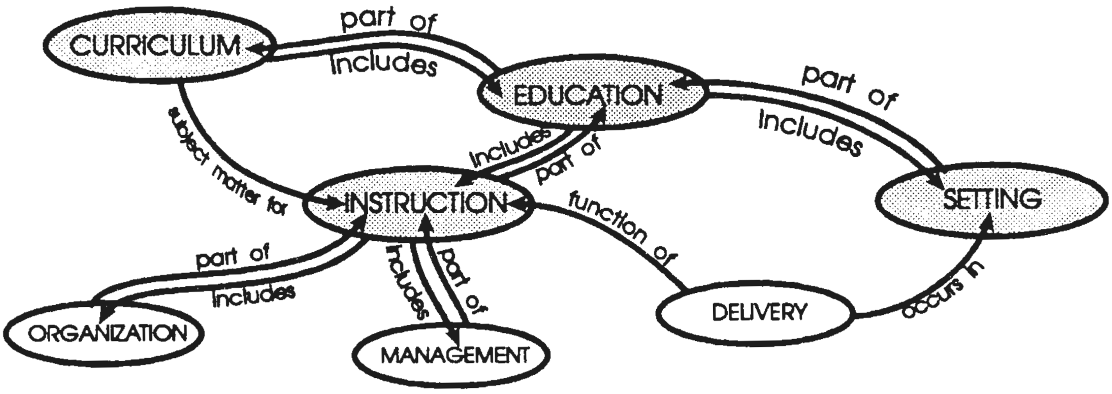
1.27 HIERARCHIES AND RELATIONAL NETWORKS

Back in Section 1.2 the domain of Education was represented in a conceptual hierarchy derived from the Canadian Centre for Learning Systems symposium series. A problem with charts like this is that they concentrate on the boxes in the chart, but do not say much about the relationships of the parts. In a conceptual hierarchy which shows the parts of a system, the reader is left to assume that each box shows a part of the more general box above it.



It is a conceptual hierarchical chart, depicting the parts-of relationships which we felt exist between the various parts of the domain of formal education. The only information provided is about the nature of the nodes. Information about the nature of the links between these nodes is lacking, but one can deduce that it is a conceptual chart.

If this two dimensional conceptual chart is expanded to provide more information about the nature of the links between the pieces, it might look like this:



This kind of diagram is a relational network. It illustrates both the nodes and the links that make up the network, and is multi-dimensional. The arrows indicate the direction of the relationship. For example, the arrow between curriculum and instruction indicates that *curriculum* provides the subject matter for *instruction*.[37]

[37] This diagram is included to illustrate the nature of relational network graphical representations. The *content* is not intended to be a rigorous representation of anything. Relational networks are a graphical way of representing a domain. They are especially useful for representing sematic networks, which in this book refer to the set of ideas and relationships which make up the inner workings of a mental model.

1.28 WHERE DO WE GO FROM HERE?

Relational networks work pretty well for simple network relationships like the one on the previous page, but as soon as the number of nodes and links gets much larger, the network becomes so complex that it is nearly impossible to depict on a two dimensional piece of paper. As our exploration of learning systems grows, each of the nodes in this network will be seen to have within them a smaller network of nodes and links. In a similar fashion, this entire network is a representation of the nodes and links that are contained within the larger node called Educational Systems. It is in turn is but one of the nodes in a network that could be called Human Development Systems, and so on and so on. It is all a matter of scale. I suspect that it would be possible to construct a massive relational network that stretched upwards to Hawking's[38] cosmos and downward to quarks with charm. There are three problems with this, however. First of all, it would be an unending job, second, it would be almost impossible to draw on a piece of paper, and third, my representation would be markedly different than yours or any other person's.

I will limit this discussion to only the node I have called Learning Systems and concentrate on the nodes within formal education that most significantly relate to the management of instruction within a learning system. The rest of this book is about managing the progress of learners through the particular formal education structure that I have defined over the last few pages as a *student-centered learning system.*

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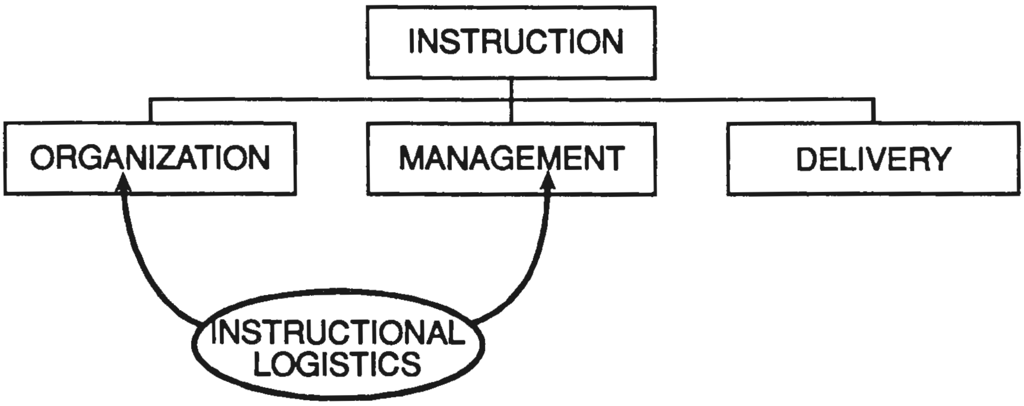
38 Hawking, S. M. (1988). *A brief history of time: From the big bang to black holes.* New York: Bantam.

PART TWO: INSTRUCTIONAL LOGISTICS

2.1 THE MANAGEMENT OF INSTRUCTION

My work is not concerned primarily with instruction itself, but with the management of instruction. I call this domain *instructional logistics* to distinguish it from Reigeluth's[1] term *instructional management*, which deals with a much wider range of concerns than instructional logistics. Instructional (or educational) management is concerned with the administration of the entire educational process, including staffing, budgets, programs, and a host of other administrative concerns. Instructional logistics is concerned with creating customized paths for each learner through a network of learning experiences. Instructional logistics strategies are limited to concerns with the movement of a student through a course, including such things as how to determine when a student should progress from one unit to the next, what an appropriate mastery level should be for particular content, or when to provide review or remediation.

Earlier, in the chart from the Canadian Centre for Learning Systems, instruction was divided up into three parts: organizing, management, and delivery. Instructional logistics is centered on the management part of instruction, but draws on organizing strategies to determine how to represent the curriculum and how to sequence the instruction.



The prescriptions that instructional logistics brings to the design of learning systems can be classified into three categories of strategies:

Partitioning strategies, concerned with dividing the curriculum up into meaningful pieces,

Manipulating strategies, concerned with arranging the pieces into an optimal path, and

Progression strategies, concerned with determining when the student should progress to the next piece.

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1 Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates. This book is often called the *Green Book* in the field.

2.2 INSTRUCTIONAL LOGISTICS

Over the remainder of this work, we will explore a number of possibilities for chopping up a program or a course into pieces that are meaningful to students and with ways to manipulate those pieces to make the subject matter more teachable. I believe this exploration might result in what Tazelaar describes as "a whole new way of looking at things," a new mindframe for viewing how we can explore making subject matter easier for students to learn.[2] At the center of this paradigm rest notions concerning mental models and the way our minds work.[3]

If these notions hold promise to inform our design decisions, we should investigate their use as tools for learning; as instructional strategies to aid understanding and teachability, and to provide sequencing strategies to optimize the order in which various aspects of a domain are presented to a learner. When I shared these ideas with David Merrill, he pointed me in the direction of Marvin Minsky's work in understanding the mind[4] and Donald Norman's thoughts on the design of everyday things.[5] These works lead me to Heinz Pagels' *The Dreams of Reason: the Computer and the Rise of the Sciences of Complexity*[6] and James Gleick's *CHAOS,*[7] the investigation of complex systems.

I have been gathering ideas from these other realms and piecing them together to speculate on their application in education. A common thread throughout these works is the idea that we construct cognitive structures in our minds which we use to represent reality. These *mental models* are the stuff of our meaningful understandings. As our mental models go, so go we.[8]

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2 Tazelaar, J. M. (1990). Object lessons. *Byte. 15* (10), 206.

3 Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster.

4 Minsky. *The society of mind.*

5 Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books. (This book is often referred to as *POET.*)

6 Pagels, H. R. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity.* New York: Simon and Schuster.

7 Gleick, J. (1987). *Chaos: Making a new science.* New York: Viking Penguin.

8 Thomas Kuhn expresses this though when he suggests that our models and paradigms not only reflect our visions of reality, but fundamentally shape what that reality becomes. Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

2.3 TAKING OUT YOUR OWN APPENDIX

When instructors are specifying the performance objectives for their lessons, they often use the forbidden phrase *to understand.* Back in the heyday of behaviorist objectives it was illegal to use the *U-word.* What can we, as instructional designers, teachers, or faculty do to help students understand? What does it mean to understand?

Let me give you an example. In the *Do-it-yourself Home Surgery* course, HS-101, there is a unit called "Appendix Removal." I ask the instructors just what they mean by the unit objectives, which include statements such as "the student will understand", and what sort of assessment measures they will use to determine if their students do, indeed, understand. I ask them which of these representative test questions would satisfy them that their objective had been achieved:

1. The students will list and describe the steps required to remove their own appendix, in the correct sequence.

2. The student will list the required steps for removing his or her own appendix in the correct sequence, and explain what each step is and why it is required.

3. The student will demonstrate, by removing his or her own appendix, the correct steps in the proper sequence, with no unacceptable loss of blood or consciousness.

4. Utilizing the knowledge, skills, and attitudes attained through this course, the student will devise and demonstrate an improved method of removing his or her own appendix.[9]

Which do we choose to assess whether the student understands? The problem is that *to understand* is too general of an objective. For many years, educators have been told to be more specific in writing behavioral objectives, but in ordinary conversation, they often express their goals as "understanding." Who, I ask, are we to suggest that the use of language be changed to obliterate the word understand? If a large number of educators want their students "to understand" something, would it not be better if we could help them develop a more precise and technical definition of understanding for use when it is required?

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[9] This measure could not, of course be done if the student had already completed item 2.

2.4 UNDERSTANDING

This problem with the term *understand* occasionally reaches the highest levels of theoretical discourse. In 1988 the participants at our Symposium Series on Instruction[10] were treated to a lively discussion between David Merrill and Charles Reigeluth on meaningful understandings. Reigeluth's recent work in this area suggests that meaningful understanding goes beyond more traditionally recognized content categories such as facts, concepts, procedures and principles outlined in Merrill's Component Display Theory.[11] Reigeluth maintains that there is more to meaning than can be expressed by combinations of facts, principles, concepts and procedures.

Merrill asked what the difference was. Merrill maintains that by properly combining the classes of ideas and levels of performance described in the Component Display Theory, instruction for meaningful understandings can be created. No more classes of ideas or levels of performance are required; the old structures need only to be combined in new ways. The issue was not resolved, but the participants were treated to a fine example of the give and take of theory building.

My current work in instructional logistics has led me into investigations in knowledge acquisition, semantic networks, and Minsky's notions about a society of mind.[12] This field provides insights into meaningful understanding that illuminate the questions outlined above. Understanding is more than being able to do. *To understand* is to be able to explain and predict. To *explain and predict* is to use principles to express knowledge in terms of causal relationships. Understanding allows one to go beyond replication of previously learned capabilities into new areas of thought or action; to do in the mind more than has been experienced in the world.

Understanding in this sense also transcends either declarative knowledge (knowledge about something) or procedural knowledge (knowledge about how to do something). It is a combination of the two plus another essential element. Minsky states:

> The quality of our understanding depends on how well we move between different realms. Our systematic cross-realm translations are the roots of fruitful metaphors: they enable us to understand things we have never seen before.[13]

This suggests that understanding of one realm depends on having some contextual link to other already-understood and similar realms that can provide initial metaphors. This is a good explanation of understanding, but what about meaning? Sometimes, we say, "I *understand* that, but what does it *mean*? What is the context?"

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10 At The Canadian Centre for Learning Systems.

11 Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

12 Marvin Minsky provides a compelling explanation of how our minds might function in his landmark work *The Society of Mind.*

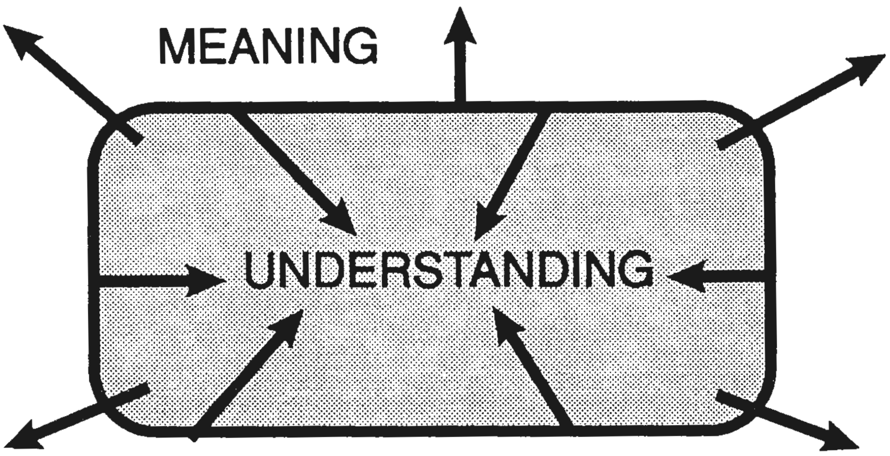
13 Minsky, *The Society of Mind,* (p. 143).

2.5 MEANING

Heinz Pagels and James Gleick describe *meanings* as contextual knowledge, knowledge of relationships between clusters of ideas.[14] Minsky proposes that our sense-making activities require placing new knowledge structures within some more global context:

> What people call "meanings" do not usually correspond to particular and definite structures, but to connections among and across fragments of great interlocking networks of connections and constraints among our agencies. Because these networks are constantly growing and changing, meanings are rarely sharp, and we cannot always expect to be able to "define" them in terms of compact sequences of words.[15]
>
> ... all ideas about meaning will seem inadequate by themselves, since nothing can mean anything except within some larger context of ideas.[16]

There are these two aspects of meaningful understandings. The *understandings* part derives from ideas and their interrelationships, a sort of internal thing. The *meanings* part derives from relationships with other clusters of knowledge, a sort of external thing.[17]



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[14] Pagels, *Dreams of reason.*

[15] Minsky, *The Society of Mind,* (p. 131).

[16] Minsky, *The Society of Mind,* (p. 200).

[17] The study of language provides further insights into the relationship between meaning and understanding. See Quine, W. V. O. (1960). *Word and object.* Cambridge: MIT Press.

2.6 ON LOOKING THROUGH THE WINDOW

Reigeluth illustrates how we can gain understanding by viewing things from different perspectives with his analogy of looking through a window into a house.[18] If we envision the part of reality that we are interested in as one of the rooms in the house, our understanding of what the reality of that room is like is limited by the view we have through that one window. This provides only one limited perception of the reality within the room. Some parts we cannot see, other parts we see from only one side. But we can form an impression of the parts of the room, the furniture, some of the walls, and so on, and how these parts fit together. Our understanding of the room is determined by our impression of all of the pieces and their interrelationships and limited by the pieces we cannot see. This analogy represents the notion that understanding is the internal aspect of knowing.

We can expand our understanding if we can find another window and look into the room from a different perspective. This new view will elaborate on the mental image we have of the reality which resides in the room and flesh out our understanding. But no matter how many different windows we look through, we will not be able to grasp the context of that reality until we relate that room to the other rooms in the house. We can gain an understanding of each room through the various windows, and a sense of how they interact by peering into all of the rooms through their many windows. This is the essence of *understanding*.

But what would happen if we stood inside the house and looked out at all of the other houses, the grass outside, and the landscape stretching to the horizon? We would then be able to relate our understanding of this particular house to how it fit into the larger picture, an outward look at the setting and other houses which probably are much the same. We could make many assumptions about what we would see if we were to look into the windows of the other houses, and we could probably comprehend how this house fit into the grand scheme of things. This represents the external aspect of knowing, which we call *meaning*.[19]

From a systems theory point of view, understanding in this sense might relate to the "within the boundaries" knowing, the knowledge of the internal aspects of the system and their relationships. Meaning might relate to the external "environment" which lies outside of the system. These two aspects of knowing, plus experience and reflection, might combine to create the seeds of wisdom.

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18 This is from a personal communication with Reigeluth, November, 1990.

19 See Lampert, M., & Clark, C. M. (1990). Expert knowledge and expert thinking in teaching: A response to Floden and Klinzing. *Educational Researcher, 19* (5), 21-23.

2.7 CONNOISSEURSHIP AND MICROFERROEQUINOLOGY

Elliot Eisner maintains that there is another level of knowing beyond meaningful understanding.[20] He uses the term *connoisseur* to describe someone who is not only an expert in a domain, but values the domain in its own right, much as a wine taster loves both the wine and the art. The connoisseur goes beyond understanding to know the subtlety and the nuance. This might be like a real estate agent looking into the house and sizing up the neighborhood.

In many ways this is similar to Bloom's notions about a person *becoming* a mathematician or a pianist or a tennis player expressed in *Developing Talent in Young People.*[21] It is also how one *becomes* a microferroequinologist.

As an example of Eisner's connoisseurship, take the domain of microferroequinology. I am a microferroequinologist of some limited renown, and certainly a connoisseur in the domain. I have an extensive array of abilities in the field, and a comprehensive body of knowledge that certainly goes far beyond what the average person would have to know about microferroequinology. All of this knowledge is wrapped up in meaningful understandings and valuings that are the result of extensive self study and a love of the domain. I have, over the years, moved from being a *dabbler in* the field to a *student of* microferroequinology to, yes, truly *become* a microferroequinologist.[22]

If the goal of a particular set of learning experiences is to foster meaningful understanding, then the nature of these experiences must go beyond teaching facts, concepts, procedures, and principles to include both the internal relationships between these notions and their contextual linkages to other realms of understanding.

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20 Eisner, E. W. (1985). *The educational imagination* (2nd ed.). New York: Macmillan.

21 Bloom, B. S. (Ed.). (1985). *Developing talent in young people.* New York: Ballantine.

22 You don't know what microferroequinology is? It is the study of small iron horses ... model railroads. The largest physical specimen of a connoisseur in our domain, who is about two metres tall and has a mass of well over one hundred kilograms is, of course, a macromicroferroequinologist. As a matter of interest, David Merrill is, as far as I know, the only holder of an honorary doctorate in Microferroequinology, granted by The Canadian Centre for Learning Systems in 1988.

2.8 MENTAL MODELS, COGNITIVE REPRESENTATIONS, AND MEANINGFUL UNDERSTANDING

This notion that meaningful understanding is the result of our knowledge of primitives such as facts, concepts, procedures and principles and the links between them, coupled with a sense of the broader context within which they reside bears a close resemblance to descriptions of mental models postulated by Norman, Minsky, and others.[23]

In *The Society of Mind*, Minsky provides an explanation of how our minds function.[24] Fundamental to this explanation is the concept of a mental model. Minsky believes that we create cognitive representations of reality by relating new perceptions to previous knowledge structures. A mental model is the cognitive representation that we create in our mind to explain things that we encounter. It is an internal representation of reality. It is what allows us to interpret the world and make sense of our perceptions. The notion of a mental model is a plausible conceptualization of the structure of our mind that closely parallels the notion of meaningful understanding.[25]

This provides a promising insight into prescriptions for determining an optimal way to partition content. Minsky suggests a unit of understanding might be "a useful and substantial collection of notions."[26] From the domain of computer interface design, Norman suggests a meaningful piece of content relates to the mental model a novice learner creates.[27]

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23 See, for example, Norman, *Everyday things;* Minsky, *The society of mind;* and Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper (Eds.). *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates.

24 Minsky, *The society of mind.*

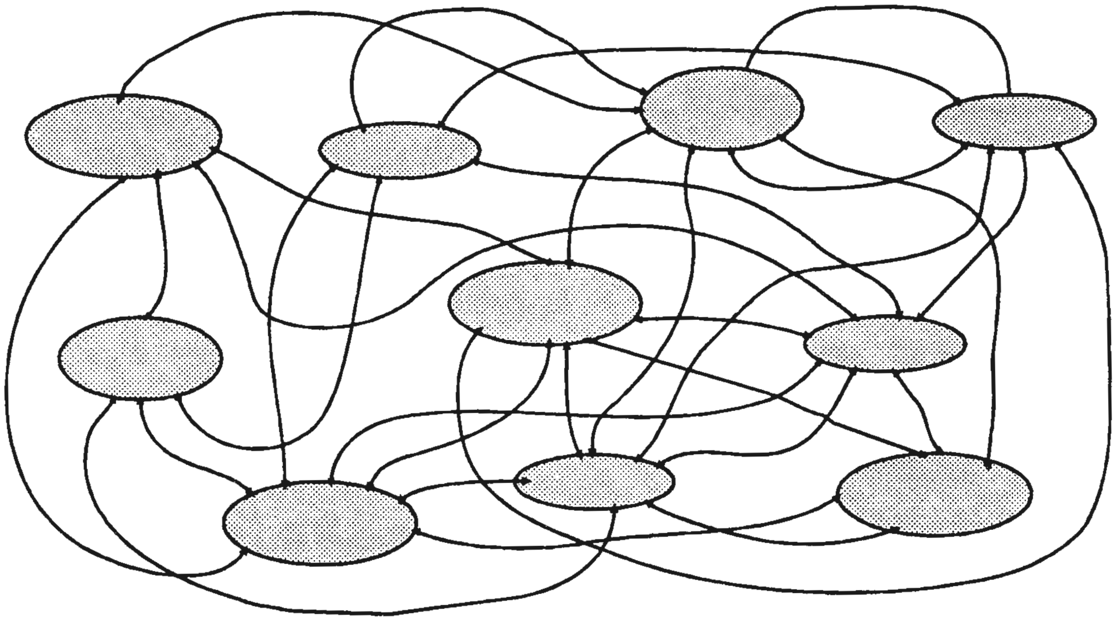
25 I believe that the description of how our minds function set out by Minsky in *The Society of Mind.* provides an extremely valuable perspective for instructional designers. It is must reading, as the critics say.

26 Minsky, *The society of mind.* (p. 92).

27 Norman, *Everyday things.*

2.9 SPAGHETTI AND MEATBALLS

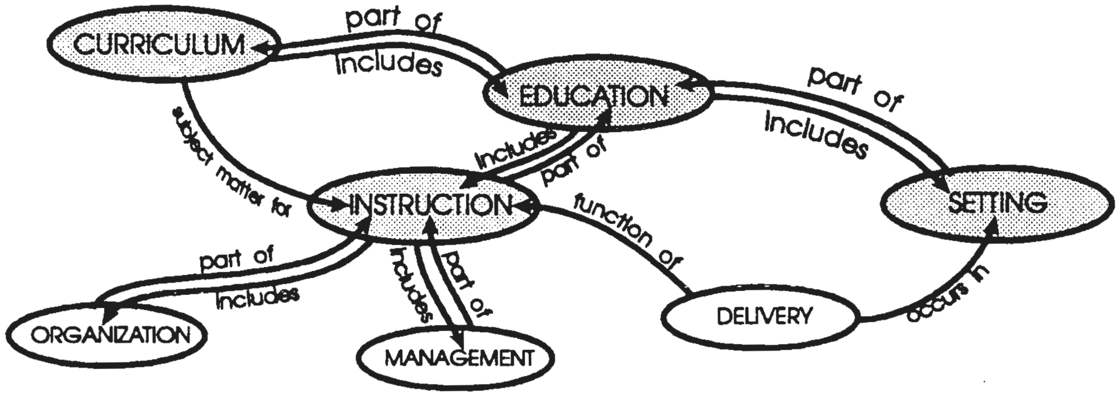
The internal makeup of a mental model is the cognitive equivalent of a bowl of spaghetti and meatballs: a semantic network comprised of a number of ideas and their relationship to one another. The ideas can be thought of as nodes in the network (the meatballs), their interrelationships as the links holding the network together and providing its structure (the spaghetti). The ideas that form the nodes are combinations of declarative knowledge about what something is and procedural knowledge about what something does; form and function.[28] The relationships that comprise the links are Minsky's structural scaffold for the ideas. One problem with analytical empirical approaches to instructional design theory is the attempt to represent these bowls of spaghetti as hierarchical two-dimensional charts. Try lining up the spaghetti. All you get is red fingers and strange looks.



[28] Minsky refers to these as structural descriptions and functional descriptions. Minsky, *The society of mind*, (p. 123). See also the references to systems theory in Part Eleven, Afterword.

2.10 SEMANTIC NETWORKS

There are more formal descriptions of the inner structure of mental models than my bowl of spaghetti and meatballs. One term from the field of artificial intelligence is a *semantic network.* A semantic network is described by Denenberg as "a declarative representation of knowledge consisting of a set of relationships between a set of topics. A convenient symbolism for a semantic network is a graph where the topics are nodes and the relationships between the topics are arcs."[29] This figure from Part One illustrates how a semantic network might be depicted with a relational network diagram.



There are two kinds of relationships: symmetric, which are the same in both directions, and inverse-relation pairs. Denenberg points out that "the important point is that there is more than one way to represent knowledge using a semantic network, and the choices made are influenced by practical considerations..."[30] They are redundant but rich representations. Denenberg also suggests the use of a semantic network to personalize instruction by using it as a map of the subject matter domain that a student can explore in a "curiosity mode."

I use the terms *mental model* and *semantic network* in a slightly different way than some theorists. I suggest that *semantic network* is a useful term to describe the interior workings of a mental model, the nodes and links. The *mental model* itself is the total unified representation that results from the development of an appropriate semantic network. For instance, a naive learner approaching a subject for the first time would initially create a simplified network of nodes and links that would be inadequate as a meaningful model of the domain. As learning continued, this web of nodes and links, which I call the semantic network, would grow and evolve into a more comprehensive representation that would provide an adequate explanation of the domain. This useful and somewhat more complete or unified web of nodes and links is a mental model. The notions of a unified whole and a meaningful piece of knowledge are what turn a semantic network into a mental model ... sort of like the Great AHA! of comprehension.

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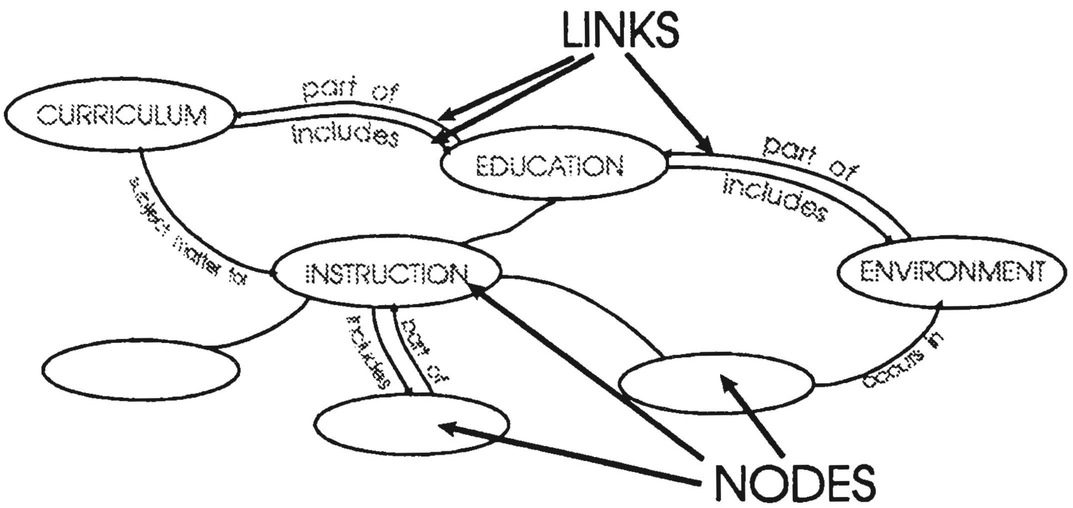
29 Denenberg, S. A. (1988). Semantic network design for courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 307-326). Hillsdale, NJ: Lawrence Erlbaum Associates. (p. 307). Denenberg discusses sematic networks and other issues related to knowledge structures in this article. Denenberg did his dissertation on this. The term semantic network is used in the artificial intelligence community to denote a somewhat less ordered structure than Denenberg's definition suggests.

30 Denenberg, *Semantic networks*, (p. 308).

2.11 MEANING AND UNDERSTANDING

Our many mental models are connected through what Minsky calls cross-realm correspondences, or external connections with other models that use the same or similar mental skills.[31] It is these connections with other models that provide the foundations of the broad context-based meanings we give to our thoughts.

A mental model, then, can be viewed as a number of nodes and links (internally) and connections to other models (externally). The nodes within a mental model are similar to the single ideas of Reigeluth's micro-level strategies.[32] They may consist of single ideas such as Merrill's facts, principles, procedures, and concepts.[33] The links are the relations between these single ideas, which have not been nearly so well defined as the kinds of ideas themselves. The nature of these links is related in some ways to the connections in the many different hierarchical structures that we educators invent, except that they are relational networks that are multi-dimensional, tangled, and often ineffable. As Minsky says, some of the things that we find the easiest to understand are the hardest to explain in words.



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31 Minsky, *The society of mind,* (p. 219).

32 Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

33 Merrill, *Component Display Theory.*

2.12 REIGELUTH-TYPE DEFINITION OF INSTRUCTIONAL LOGISTICS

In *Instructional Design: What it is and Why it is,* Reigeluth[34] provides formal definitions of many instructional design terms. This is a definition of instructional logistics which parallels Reigeluth's others.

Instructional logistics is concerned with understanding, improving, and applying methods of managing the progression of a learner through an instructional program. It is much narrower than instructional management in that it deals only with the creation of a customized path for a learner through a program of instruction. As a professional activity, it is the process of prescribing and using optimal strategy components to partition the curriculum into both meaningful and manageable pieces, and with the manipulation of those pieces to create a path for the learner through the instruction to maximize the benefit gained from the learning experience. The result of instructional logistics as a professional activity is a learning system that guides the student through an optimal progression of learning experiences.[35]

The discipline of instructional logistics is concerned with producing knowledge about diverse customizing principles, optimal combinations of principles, and situations in which each of these principles is optimal.

An underlying assumptions of instructional logistics is that a body of knowledge exists that can be used to prescribe an optimal path (sequence of learning experiences) for a learner to match the needs of the learner with the characteristics of the subject matter and the environment.

The Chunque Theory is a speculative instructional logistics theory comprised of a set of defined concepts, a set of instructional propositions, and a tentative set of conditions under which these propositions might be used. It is partly a descriptive theory, in that it describes in a new way the domain of instructional logistics, its parts, and its functions. It is partly a prescriptive theory, in that it describes how instructional logistics strategies might be incorporated into the design of student-centered learning systems. But, most of all, it is a first step in creating a "whole new way of looking at things."[36]

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[34] Reigeluth, *Instructional design: What is it,* (pp. 3-36).

[35] The format of this definition is derived from, and is consistent with that used in Reigeluth, *Instructional design: What is it,*

[36] Tazelaar, J. M. (1990). Object lessons. *Byte, 15* (10), 206.

2.13 SYNTHESIS

The point of this section has been to suggest that in order to design an effective, efficient and enticing learning system that provides customized instruction for each learner, it is necessary to partition the curriculum into meaningful and manageable pieces and to manipulate those pieces to create an optimal sequence of learning experiences. Instructional logistics strategies are used to manipulate the pieces to create a customized path through the instruction for each learner.

I believe that we should use the notions about mental models as a basis for designing learning systems. As Minsky and Norman point out, as far as we can tell, people do construct mental models to explain new things. Students are going to construct mental models whether we intentionally build them into our instruction or not. As Norman suggests,

> *We base our mental models on whatever knowledge we have, real or imaginary, naive or sophisticated. Mental models are often constructed from fragmentary evidence, with but a poor understanding of what is happening, and with a kind of naive psychology that postulates causes, mechanisms, and relationships even when there are none.*[37]

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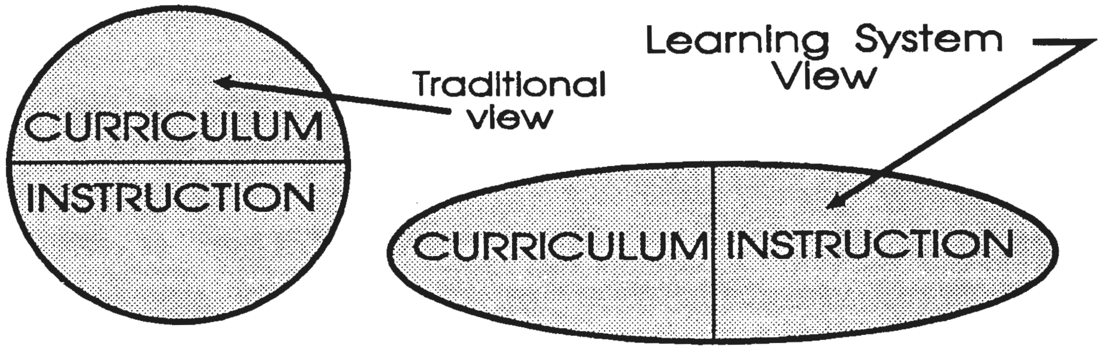
[37] Norman, *Everyday things*, (p. 38).

PART THREE: REPRESENTING A CURRICULUM

3.1 CURRICULUM AND INSTRUCTION

In order to begin to think about learning systems and how to design them, we need to have a common understanding of the distinction between curriculum decisions and instructional decisions. The first few pages in this section provide definitions for my particular usage of a number of terms that are common to instructional design literature. It seems that educators typically see the domain of education divided into two parts, curriculum and instruction, with the notion of curriculum seen as the higher level part of the domain and instruction as the lower level:



In chunque-based learning systems, I see a very sharp distinction between curriculum and instruction that divides the domain of education in a vertical split. All decisions regarding *what to present* to the learner are *curricular* decisions. Curriculum is concerned with *what to teach.* All decisions regarding *how to teach* the curriculum are instructional decisions. Instruction is concerned with *how to teach it.*[1]

Curricular decisions, regarding what ideas to present to the learner range from the most broad educational goals such as "a sense of citizenship" down to the most minute task analysis determinations, such as "how to adjust a control."

There is in my view a third part of education which I call the *setting* in which the learning takes place, including the facilities and resources, and the culture or climate of the setting. Another way to express this is that curriculum is concerned with what is taught, instruction is concerned with how it is taught, and environment is concerned with where it is taught. Discussions of the implications of the educational environment are beyond the scope of this work, but of significant importance in the overall design of learning systems.[2] I have reluctantly excluded environmental considerations except where their effect is crucial.

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1 Glen Snelbecker makes this distinction in Snelbecker, G. E. (1983). Is instructional theory alive and well? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 437-472). Hillsdale, NJ: Lawrence Erlbaum Associates.

2 Miami-Dade Community College is an outstanding example of an institution that has considered all three of these factors in developing a superlative educational system. A report of their successes and concerns can be found in Roueche, J. E., & Baker, III, G. (1986). *Access and excellence.* Washington: American Association for Community and Junior Colleges.

3.2 GOALS

What are we trying to do when we develop an educational program? We might be trying to add to the capabilities of the learner. We might be trying to teach the learner to become a pilot; to operate an airplane. Or we might be trying to teach the learner to act like a Prince; to conform to the image of a monarch.

Whatever ideas we are trying to instill in our students, they are based on someone's conceptualization of value. The ideas are judged to be of sufficient worth (either to the learner or to the program developer or society) to take the time and effort to instill them in the learner. This judgement of the value of the ideas is usually established by society (in public education) or by the management of a company or agency (in corporate training). Regardless of the source of the value judgement, the content of a curriculum is inevitably set by some determination of worth.

The goals of a curriculum are the result of identifying the nature of the ideas to be included in the program. Goals are broad statements about the kinds of changes in the learner that should result from a successful educational program. Goals are usually not stated in measurable terms. They are usually general statements defining in broad terms what the result of the program should be for the learner (and society?).

A useful analogy to the spectrum of capabilities represented by curricular goals is the sticker on the window of a new car which specifies of what it consists. A quick check of this sticker will give the prospective purchaser a yardstick to measure the specification of the particular car in comparison to the needs of the buyer. The sticker lists what is included in the package (somewhat analogous to "capabilities" in many instances) without detailing what was entailed in providing those capabilities.

The important characteristic of educational goals is that they are always based on someone's conception of worth. The "someone" should include all stakeholders in the program.

The terms curricular outcomes, accomplishments, and capabilities are often used to describe in a most general sense what it is that a program is expected to provide for a learner. At the most global levels, these outcomes are commonly called goals, while at the more precise levels, curricular outcomes are usually referred to through objectives.

3.3 OBJECTIVES OR CAPABILITIES?

How can curricular goals be transformed into tools that can be used to design an instructional program? This raises a problem. Some educators, like Elliot Eisner,[3] suggest that the goals of a program should be loosely defined, leaving the teacher or instructor with the challenge of creating an educational environment where the ultimate outcome, but not necessarily the specific activities, are in alignment with the intent of the curriculum.[4] Instructional systems design generally suggests that the goals must be restated in concrete terms, including a definition of the learner's measurable capabilities.[5]

I believe that there is room for both of these positions in the field of learning system design, and will delve into this problem later, but for now I will side with the systematic school of instructional design, and explore what is involved in transforming goals into measurable accomplishments.

These transformed goals are usually called objectives. An objective is a more technical specification of precisely what it is that we want the learner to be able to accomplish upon completing an instructional program.[6] Objectives translate the value laden goals of the curriculum designer or stakeholders into specific ideas that must be learned in order to assure that these goals are met.

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3 Eisner develops this position in an elegant fashion in Eisner, E. W. (1985). *The educational imagination* (2nd ed.). New York: Macmillan.

4 Liberal Arts curriculum people subscribe to this type of educational setting, as in Adler, M. J. (1982). *The paideia proposal: An educational manifesto.* London: Collier Macmillan

5 Gagne suggests that what students should learn are not *skills*, but the *capability* of performing skills. See Gagne, R. M. (1987). Introduction. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 1-10). Hillsdale, NJ: Lawrence Erlbaum Associates. At the The Canadian Centre for Learning Systems symposia, Ken Carlisle called these capabilities "accomplishments." See Carlisle, K. (1986). *Analyzing jobs and tasks.* Englewood Cliffs, NJ: Educational Technology Publications.

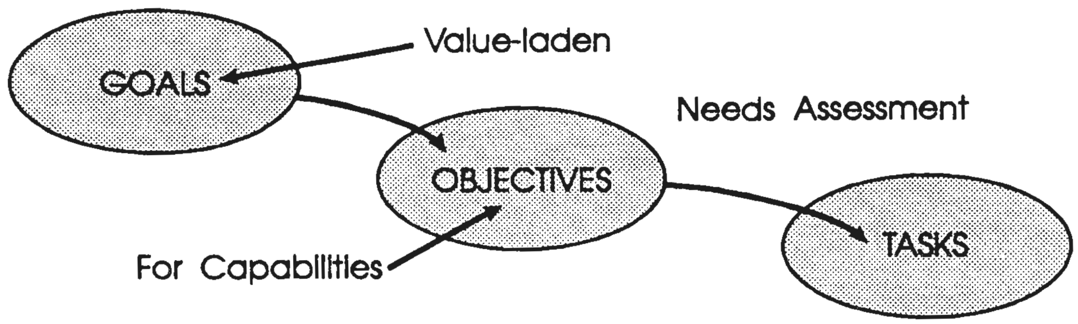
6 Ken Carlisle defines the outcomes of an instructional program as accomplishments, and makes the point that, in training programs, it is the accomplishment that is important, rather than the behavior that results in the accomplishment. While this idea is fine for training programs, it causes me some concern when the goal of the program might be to alter a learner's behavior. Recall the old adage "You are hired for your knowledge, and fired for your personality." This distinction between behavior and accomplishments also bears close scrutiny when we talk about behavioral objectives.

3.4 NEEDS ASSESSMENT AND TASK ANALYSIS

The discipline that is concerned with the identification of program goals is *needs assessment.*[7] The product of needs assessment is a statement of program goals. This statement defines the desired changes between what the current situation is and what the ideal situation should be. It is a comparison of the present state and the desired state to determine what the gaps are. The learning system must be designed to help the learner bridge those gaps. Generally, the identification of gaps should be done by a wide range of stakeholders.

A precise definition of the capabilities that comprise the gaps is created by curriculum design procedures such as needs assessment or DACUM analysis.[8] These procedures identify the component skills, attitudes, knowledge, and capabilities that are required by competent practitioners within the domain.

The creation or identification of program objectives lies in the domain of *task analysis* or *needs analysis.* These activities are concerned with breaking down the capabilities identified in curriculum design into individual tasks that must be mastered in order to accomplish the goals.[9] It is a more technical activity that is somewhat removed from the value judgements inherent in setting curricular goals.



It is interesting and important to note that objectives which result from these processes are usually not so value-laden as program goals. The description of goals is inherently a value laden-activity. It should probably be carried out by laymen rather than designers, even though designers are often charged with the task of formulating curricular goals. In this case, it is essential that the designer validate program goals with the stakeholders that want the program in place.

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7 See Rossett, A. (1987). *Training needs assessment.* Englewood Cliffs, NJ: Educational Technology Publications.

8 The DACUM process uses a panel of expert practitioners to develop a chart of job competencies. See Nolan, T. D. (1990). *The DACUM process training manual.* Cincinnati, OH: Cincinnati Technical College.

9 In the DACUM manual, these are called *tasks* and *steps.* See Nolan, *The DACUM process.*

3.5 THE QUESTION: HOW CAN WE KNOW WHAT WE REALLY WANT?

Learning system design proposes that the initial specification of the capabilities required in a learning system be formulated in the specification of *assessment measures*. An assessment measure is a representative example of the kind of test item that will be used to determine whether a learner has mastered a capability. It is an objective with the added specification of how it will be assessed.[10] This will be discussed at considerable length in Part Eight, Assessment and the Pursuit of Excellence.

The power of assessment measures rests in an accurate description of what changes we want as a result of the learning experience. The ultimate success of the program depends on identifying precisely what the desired capabilities are, and then constructing assessment measures that truly measure whether a learner can do those things.[11] This process of precise definition of accomplishments can be simplified if we can find a method of classifying different kinds of goals and objectives. As Merrill points out, different kinds of goals demand different levels of performance. They also demand different kinds of assessment measures to evaluate that performance.

For example, the goals of a program designed to produce pilots would be fundamentally different than the goals of a program designed to produce Princes. Not necessarily because pilots are different learners than Princes, but because the desired accomplishments are so different. I believe that the *kinds* of ideas that are incorporated into programs to produce pilots or Princes are fundamentally different. The very nature of the program goals must be different because the products of these programs are so different.

This fundamental difference in the kinds of program goals and in the kinds of capabilities that are necessary to achieve these goals was recognized by Robert Browning.

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10 Merrill demonstrates the use of assessment measures in his CDT chapter in Reigeluth's *Green Book*, but does not use this term. See Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

11 This idea is stressed by George Gropper in the *Green Book*. See Gropper, G. L. (1983a). A behavioral approach to instructional prescription. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 101-161). Hillsdale, NJ: Lawrence Erlbaum Associates.

3.6 ROBERT BROWNING: INSTRUCTIONAL DESIGNER

A Death in the Desert

This is the doctrine he was wont to teach,
How divers persons witness in each man,
Three souls which make up one soul: first, to wit,
A soul of each and all the bodily parts,
Seated therein, which works, and is What Does,
And has the use of earth, and ends the man
Downward: But tending upward for advice,
Grows into, and again is grown into
By the next soul, which seated in the brain,
Useth the first with its collected use,
And Feeleth, thinketh, willeth, - is What Knows:
Which, duly tending upward in its turn,
Grows into, and again is grown into
By the last soul, that uses both the first,
Subsisting whether they assist or no,
And, constituting man's self, is What Is -
And leans upon the former, makes it play,
As that played off the first: and, tending up,
Holds, is upheld by, God, and ends the man
Upward in that dread point of intercourse,
Not needs a place, for it returns to Him.

What Does, what Knows, what Is; three souls, one man.

Robert Browning[12]

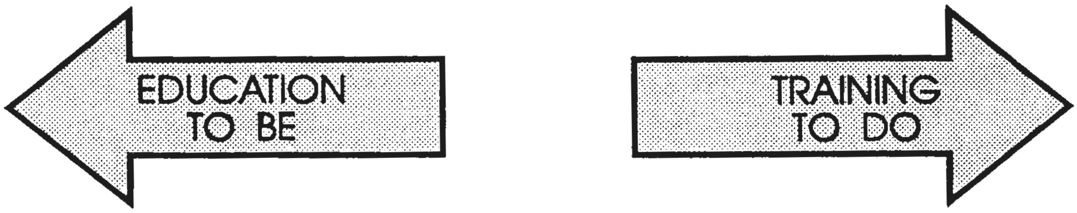
[12] This poem can be found in Rowntree, D. (1987). *Assessing students: How shall we know them* (2nd ed.). New York: Nichols.

3.7 THREE SOULS

Three souls, one man. How does this apply to the design of learning systems? I think Browning discovered a tool that can be of great value to us when we classify the kinds of capabilities we want our students to possess. Browning hit on an idea that can be used to simplify the spectrum of kinds of ideas into the three categories of his poem: "What Does, What Knows, What Is." This is a powerful idea.

Let's look at the program to produce pilots. What is the essence of what a pilot must be able to do? Michael DeBloois[13] quotes an old line from the field of competency based instruction that states the mastery level for pilots has to be 100%. If I am in the plane, I want the pilot to be able to perform every cognitive and motor skill necessary to get the plane from where it is to where I am heading without the slightest possibility of error. An 80 percent mastery level just is not good enough. Although we all appreciate the airline pilot who provides those extra touches of comfort when we fly, we are concerned primarily with *what Does.*

To get to the essence of "Prince-ing" on the other hand, I don't really care what a Prince can do. I am much more concerned with what he appears to be. I want him to *be* a Prince. *What Is.* The program for Princes and the program for pilots have fundamentally different kinds of goals. These different kinds of goals require different kinds of instruction and different kinds of assessment measures. I call the kinds of goals in the Princes' program *Education-to-Be.* The pilot requires primarily *Training-to-Do.*



This brings up an interesting point. What is this book trying to do? What is the goal? Is it Education-to-Be? Is the point to change the essence of what you are? Is it Training-to-Do? Is this a book to train you how to create learning systems? It is neither. The goal of this volume is to have you understand the language of learning system theory, and to have you recognize the underlying principles that combine to provide a model of student centered learning systems and where it fits into the grand scheme of things. It doesn't fit either of these two categories. We'll see where it does fit later.[14]

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13 Michael DeBloois used this example in a seminar in Logan, Utah, 1984.

14 Notice that when I try to clarify the goals of this book, I retreat into forbidden terminology: "to understand."

3.8 EDUCATION-TO-BE

What does our Prince and a Marine have in common? Not much, I hear you say. But wait. They both have an *image*. An essential part of what a Prince is or what a Marine is is embodied in their image of what they are. Embodied into the education received by both Princes and Marines is a very heavy does of image making. The right stuff. "The battle of Waterloo was won on the playing fields of Eton."[15]

Education-to-Be is concerned with creating Bruner's[16] better, happier man; with changing the underlying characteristics of the learner to mould and shape a new man. Prime ministers and Kings send their children to educational institutions that espouse Education-to-Be. Finishing schools and the Priesthood are concerned with Education-to-Be, with moulding the learner to *become* a socialite or a man of the cloth.[17] Of course, programs that lean toward Education-to-Be must also have a strong emphasis on the necessary cognitive skills and other capabilities required to be whatever it is that the program is producing. The point here is that the kinds of instructional programs (and the kinds of assessment measures) required to create optimal learning systems in the domain of Education-to-Be are different than those for Training-to-Do.

Recognizing that there are different kinds of objectives, instruction, and assessment measures for different kinds of goals permits us, in designing a learning system, to prescribe optimal solutions to instructional problems.

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15 From *Words on Wellington* by Sir William Fraser. (1889).

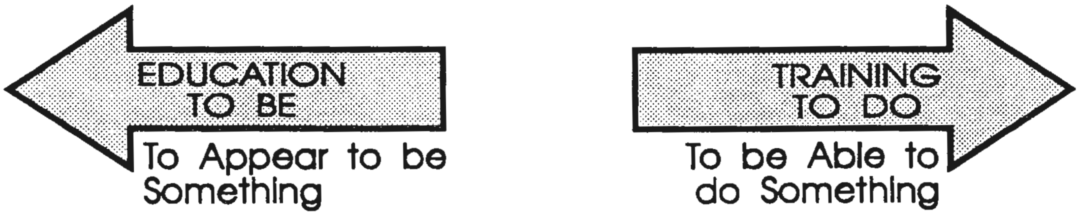
16 Bruner, J. S. (1966). *Toward a theory of instruction.* New York: Norton.

17 Benjamin Bloom addresses this idea, which he calls *internalization*, at great lengths in his book *Developing talent in young people.* He did an extensive qualitative study of talented individuals in sports, music, medicine and scholarship to try to identify what it was in their upbringing that contributed to their success. I was struck by Bloom's description of a music student "becoming" a pianist. This to me is the essence of Education-to-Be. See Bloom, B. S. (Ed.). (1985). *Developing talent in young people*. New York: Ballantine.

3.9 TRAINING-TO-DO

Training-to-Do is concerned with performance improvement. The military and industrial trainers are often primarily concerned with skill development and measurable improvements in learned capabilities.

Education-to-Be and Training-to-Do can be viewed as opposite ends of a continuum of kinds of goals. Training-to-Do is concerned with the skills necessary to do something.



For many years, the field of instructional design was focussed almost entirely on Training-to-Do, to the exclusion of anything else. This, I suspect, was partly because B. F. Skinner thought that every capability that man could obtain was Training-to-Do. To Skinner there simply was nothing else.[18] Also, systematic instructional design has its roots in the behaviorist tradition, beginning with the work of Gagne and Briggs[19] and many others during the second world war. Behavioral objectives are based on the notion that practically anything that a student should learn can be transformed into a specific observable behavior for which a precise performance objective can be written. Under this doctrine, instructional designers tend to regard training-to-do as the only kind of learning, and the definition of the concept *to-do* tends to be expanded to become all inclusive.

While there is no question that a large portion of the expected student outcomes or capabilities in many programs falls into the realm of training-to-do, I maintain that it accounts for only one of the major categories of knowledge.

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18 For a fine example of Skinner's behaviorism, see Skinner, B. F. (1971). *Beyond freedom and dignity.* New York: Knopf.

19 Gagne, R. M., & Briggs, L. J. (1979). *Principles of instructional design* (2nd ed.). New York: Holt, Rinehart, Winston.

3.10 THE INSCITE PROBLEM

At the start of this book, I spoke about the INSCITE program, and our realization that none of the content in the course was really justifiable in its own right. I would like to elaborate on that a bit.

The primary goal of the INSCITE program was to give the students an awareness of the impact of technology on life in our society. This caused a couple of problems for traditional instructional designers. On the one hand, the behaviorist school of thought will not accept "awareness" as an objective, because it is not a measurable outcome. It is not concrete enough. They want to know precisely what awareness entails. On the other hand, it would appear that creating assessment measures for awareness would be difficult. How do you say "Dixie is aware, but Dave is not?"

For us, the problems were different. When we looked at the list of fifty or so learning experiences that we used to represent technology, we begin to question whether any one of them was crucial to the mind frame of our students. As I pointed out earlier, we decided that there really was not one single item of content that was crucial in the sense that, if a student did not master it, they could not "pass the course."

We came to the conclusion that the details of what the students learned about any particular process, like photography, or metalwork, was not the essential issue. It was a broad understanding that we were after. Behavioral objectives did not seem to work. We felt it did not really matter what particular things the students learned about technology, as long as they learned something about how it fit into their lives and what some of the commonalities were. So we begin asking them, "Well, what did you learn?" Finally, we came up with a useful assessment measure. We created a standard examination that we called simply an Evaluation Sheet which the students completed whenever they finished *any* learning module. It asked questions that we felt got at "awareness" and broad understanding. Questions like "How does the process work?" "What other processes does it relate to?" and "What is the industrial significance of this process?"

I think we discovered a gap between Education-to-Be and Training-to-Do. This gap is the domain of meaningful understandings, where a learner knows *about* something, but maybe cannot *do* much with that knowledge. This is much like the distinction Gleick[20] makes between experimental and theoretical researchers. Theoretical researchers manipulate ideas, a *to-know* activity. Experimental researchers manipulate things, a *to-know* plus a *to-do* activity.

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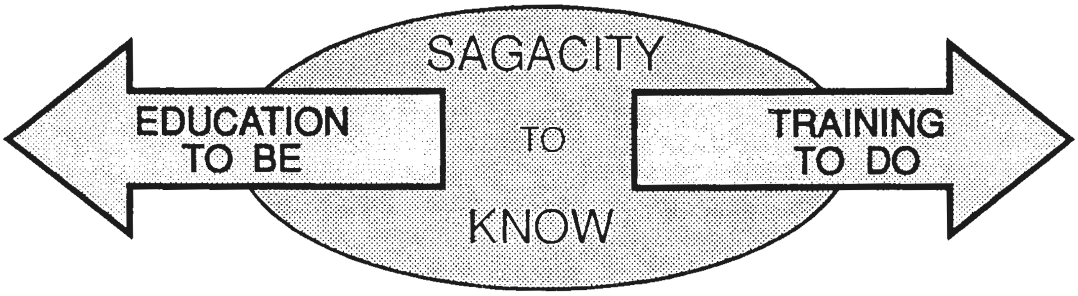
20 Gleick, J. (1987). *Chaos: Making a new science*. New York: Viking Penguin.

3.11 SAGACITY

I believe that the strong history of behaviorism in instructional design, and the influence of a training-to-do perspective has resulted in a force fit[21] of many ideas into a rigid "measurable outcomes" model of instruction. Although this model has proven valuable, it might not be as useful as other conceptualizations on a more global scale.

This domain of knowledge about something is, I believe, closely related to Reigeluth's meaningful understandings, the AI scientist's declarative knowledge, and Browning's "to Know". But it has also to do with interrelationships. I call this domain falling between Education-to-Be and Training-to-Do, where specific skill development or fundamental changes in the character of the learner are not the aim, Sagacity-to-Know. This domain comprises a middle ground, the large body of knowledge that makes up the bulk of our understanding of the world.



The field of knowledge acquisition from artificial intelligence discusses the difference between declarative knowledge (knowledge about something) and procedural knowledge (knowledge about how to do something). I believe that sagacity-to-know is in some ways related to declarative knowledge, and training-to-do is related to procedural knowledge. Browning added the essence of humanity, education-to-be, the knowledge of what we are. Burns and Capps add a third category, *qualitative* knowledge, the causal understanding that allows one to reason about behaviors.[22]

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21 This idea of a force fit comes from Jacob Bronowski who describes creativity in science and art. It is a nice counterpoise to Eisner's expressive objectives. See Bronowski, J. (1956). *Science and human values*. New York: Harper and Row.

22 Burns, H. L., & Capps, C. G. (1988). Foundations of intelligent tutoring systems: An introduction. In M. C. Polson & J. J. Richardson (Eds.). *Foundations of intelligent tutoring systems* (pp. 1-19). Hillsdale, NJ: Lawrence Erlbaum Associates.

3.12 SAGACITY-TO-KNOW AND MEANINGFUL UNDERSTANDINGS

Webster's defines sagacity as *a keen perception.* My electronic thesaurus lists as synonyms *acumen, astuteness, awareness, insight,* and *understanding.* That sounds to me much like the meaningful understanding in Part Two. Meaningful understanding is the missing middle. It encompasses the very large chunk of curricular goals that bridge the gap between Education-to-Be and Training-to-Do on the continuum of goals. I think meaningful understandings are the third part of Browning's three souls, the "what knows" part. I maintain that this domain of curricular ideas is a very important area of curriculum that has been largely ignored in systematic instructional design. We will come back to this later.

When we look at the remember/use/find performance levels of the Component Display Theory,[23] this notion of sagacity seems to slip through the cracks somewhere. *Remember* certainly does not capture the essence of sagacity. Neither does *use. Find* seems a bit closer, but sagacity might be better described as the background knowledge that supports the ability to *find* something new, and the wisdom to judge its worth. To me sagacity-to-know seems more to imply the relational understanding and contextual meaning that comes from integrating facts, concepts, procedures, and principles into a meaningful whole.

This figure illustrates Merrill's matrix, with levels of performance running vertically, and kinds of content running horizontally. Merrill points out that there is no category for find-fact or use-fact.

	Facts	Concepts	Procedures	Principles
FIND	XXXXX			
USE	XXXXX			
REMEMBER				

The point here is that *meaningful understandings* are indeed comprised of facts, concepts, procedures and principles that are assembled in a particular way. But the result of this assemblage is a particular kind of understanding that transcends the atomic perspective of facts, concepts, procedures, and principles considered in isolation.

Recall the earlier observation of Bloom[24] regarding all of the terms and facts he found in textbooks. These to me are the nodes within the nodes of minimal mental models, the most reductionist notions that we deal with. While terms and definitions are essential pieces of any mental model, no matter how many a student learns, they alone cannot provide the understanding, the meaning, or the sagacity to truly know.

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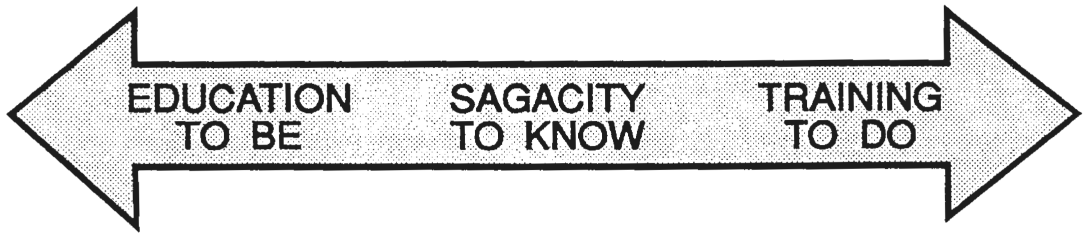
23 See Merrill, *Component display theory.*

24 Bloom, B. S. (1976). *Human characteristics and school learning.* New York: McGraw-Hill.

3.13 CURRICULAR GOALS AND INSTRUCTIONAL STRATEGIES

What we have been exploring in the last few pages is the idea that there are fundamentally different kinds of educational goals that require different design strategies and different instructional programs. The continuum of educational goals looks like this:



If we take a look at this continuum, and relate it to Bloom's cognitive, affective, and psychomotor domains,[25] there does not appear to be a very close correspondence. The cognitive domain seems in some ways to collect at the Training-to-Do end of the scale, and lap into the Sagacity-to-Know portion. The affective domain might be seen to extend from the Education-to-Be end in towards the middle. Education-to-Be is more concerned with attitudes and human characteristics. Training-to-Do is concerned more with skills and competencies. The middle, the Sagacity-to-Know area, is concerned with understanding the underlying principles that make things happen the way they do. I think this might properly be called "essential education", getting at the essence of the ideas, but the term "essential" would be misconstrued.

The psychomotor domain doesn't seem to fit. It seems to lie along a different dimension. While there is no question that a large part of the to-do area is composed of psychomotor skills, those skills somehow do not seem to be very similar to Browning's three parts of the soul of man. I suspect that all three of these domains, to be, to know, and to do, refer more to the mental aspects of the endeavors. It seems that both Bloom's cognitive and affective domains have a great deal to do with what goes on in the mind of man. That is a totally different thing to me from what psychomotor skills entail. I am not trying to give psychomotor capabilities the short shift here. There is no question that the development of motor skills is an important part of education and training. I simply think it is a very different thing from the mental gymnastics required in any of the domains noted above.

The essential difference between the cognitive/affective/psychomotor split and the three souls continuum is that the three souls cuts across the cognitive affective and psychomotor domains based on the *intention* of the learning experience. The three souls seems to get at a more subtle and certainly not self-evident distinction between the kinds of goals or purposes for programs.

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[25] Bloom, B. S., (Ed.). (1956). *Taxonomy of educational objectives, handbook I: Cognitive domain.* New York: David McKay.

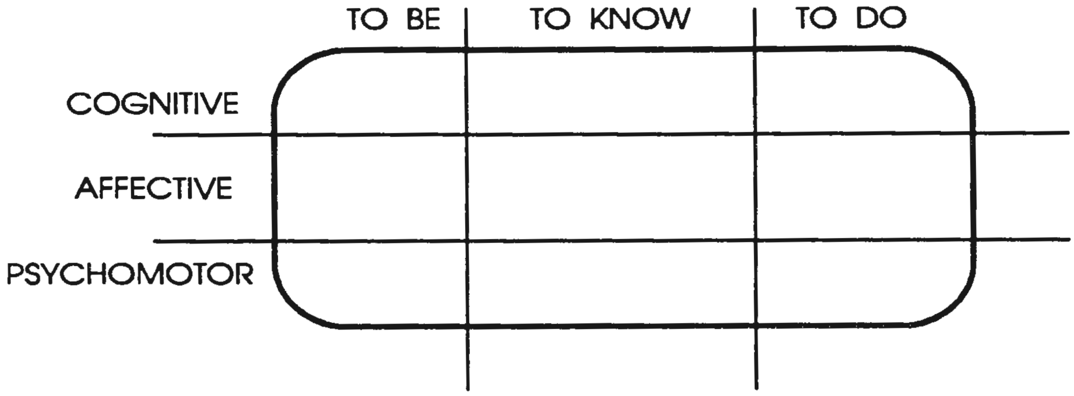
3.14 MATCHING GOALS AND THE THREE SOULS

When I first mentioned the Marine in section 3.8, I imagine that many of you immediately though of training. After all, the military and training are practically synonymous. While there is no question that military personnel receive a healthy dose of training to perform their jobs, the Education-to-Be component is still there. The generals want the troops to be able to do many things, but they also want them to be "soldiers." Interestingly, I suspect that the generals are not too concerned with what the troops understand in the Sagacity-to-Know area.

Questions to ponder are these: If it is helpful to learning system designers to view educational goals lying along a continuum like this, how can we create optimal curriculum descriptions that point out these differences? Who should do this? Curriculum committees comprised of lay people, or trained professional instructional designers?

How can we design optimal learning systems that have instructional resources and assessment measures which provide learning experiences to match the different kinds of goals? In the next section these issues will be addressed.

Here is something else to ponder. What happens if we draw a three-by-three matrix with the three souls labelling the columns and Bloom's domains labelling the rows: goals across the top and capabilities up the side? What fits into each cell? And what do the cells tell us about the design of learning systems?



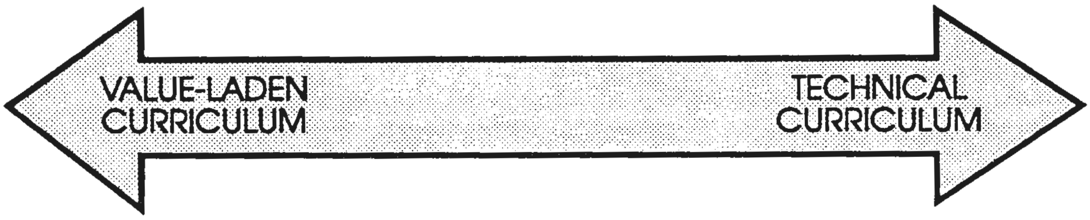
You got me. This question falls into the realm of *further research agendas.*

3.15 THE VALUE LADEN AND TECHNICAL CURRICULUM

Earlier on I described the distinction between curriculum, the *what to teach*, and instruction, the *how to teach it.* In this section the idea of curriculum decision making as a continuum ranging at one pole as a value laden domain and at the other pole as a primarily technical activity will be expanded. The significance of this continuum to learning system design will be explored.

Curriculum decisions are decisions concerned with what it is that we want to pass on to our learners. There are two kinds of curriculum decisions that must be made in the development of an educational program. The first of these are *value laden* curriculum decisions, which are concerned with selecting worthwhile or valued ideas to include in a program. Value laden curriculum decisions are the concern of curriculum committees, politicians, philosophers, and all other stakeholders concerned with what it is that the student should know. In much of the curriculum design literature that I have encountered, the value-laden curriculum seems to be the only curriculum that is explored in any depth.

However, there is a second domain of decisions regarding what to teach. This second kind of curriculum decisions are *technical* decisions, concerned with determining what kinds of things a learner must know in order to fulfill the expectations of the value-laden curriculum. These technical curricular decisions are typically the concern of educational practitioners who are charged with the responsibility of passing on the value-laden curricular ideas to the learner. This activity of defining a technical curriculum is similar to task analysis, which is typically thought of as an *instructional* activity rather than a curricular activity. In my view, task analysis is a *technical* curricular activity, as task analysis is concerned with determining precisely what capabilities must be included in the curriculum.



The curriculum continuum stretches from highly value laden choices to very precise and detailed choices of individual transactions with the learner which will, it is hoped, carry the value laden ideas to that learner.

3.16 THE BOY SCOUTS

To illustrate the distinction between the value-laden and the technical curriculum, consider this Boy Scout example. A stakeholders' committee of parents, club organizers and officials, and perhaps recreation consultants (and in enlightened situations, the boys themselves) selects the kinds of things that they would like included in a program. The selection of what particular things to include is based on a determination of their worth or value.[26] These are value-laden curricular decisions. A specific example might be a decision to include knot tying as an activity, with six particular knots selected as appropriate.

Armed with a profile of valued things to include in the program, educators must determine what has to be learned in order to ensure that the program is successful, and the goals are reached. The product of this determination of what must be included in order to achieve the goals of the program is the *technical curriculum*, and is usually left up to the educators to select. A specific example might be the several distinct kinds of manipulations required to form a particular knot that is included in the program.

This proposition is based on Gagne and Briggs,[27] who use a similar distinction in their definition of target objectives and enabling objectives. A target objective could be an instructional outcome that is deemed to be worthwhile in its own right. A set of enabling objectives are instructional outcomes that together provide the capability of attaining the target objective. Enabling objectives do not have a great deal of value in their own right. They are necessary prerequisite capabilities.

Chunque Theory	Gagne & Briggs	Tools
Value-laden Curriculum	Target Objectives	Needs Assessment
Technical Curriculum	Enabling Objectives	Task Analysis

This chart illustrates a possible set of relationships among the concepts of chunque-based learning systems, Gagne and Briggs' notions and the curriculum analysis tools discussed earlier.

26 This determination of worth could be based on many considerations, as diverse as cultural values or politically desirable items necessary to insure funding, but the selection is based on some determination of value.

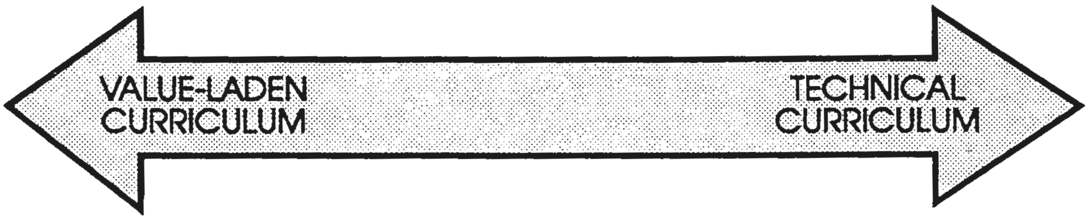
27 Gagne & Briggs, *Instructional design.*

3.17 THE CURRICULUM CONTINUUM

The curriculum continuum, from value-laden to technical, bears a relationship to the Three Souls continuum of educational goals described earlier:

Three Souls Curriculum Continuum

Continuum of Educational Goals



There is more emphasis in Education-to-Be on the value-laden end of the continuum, which follows because in Education-to-Be the intention is to instill notions of worth. As a result, more of the ideas comprising a course of this nature would relate to the affective domain (or Education-to-Be). Similarly, in Training-to-Do the curricular emphasis is directed more toward the technical pole of the continuum. This difference can be seen in reflecting on the degree of public interest generated by proposed changes in Education-to-Be type programs such as citizenship, compared to programs related to Training-to-Do, such as welding.

Also, there seem to be more intractable instructional design problems associated with notions closer to the value-laden end of the curriculum. Martin and Briggs address some of these issues in their work on the relationships between the cognitive and affective domains.[28]

Another interesting characteristic within typical program design situations is the changing interest of curriculum designers, boards of directors, school boards and lay groups as decisions shift from the value-laden curriculum to the technical curriculum. At some point the stakeholders in the program simply lose interest and leave the decision making to the educators.

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[28] Martin, B. L., & Briggs, L. J. (1986). *The affective and cognitive domains: Integration for instruction and research.* Englewood Cliffs, NJ: Educational Technology Publications.

3.18 SUBJECT MATTER DOMAINS

The value-laden goals expressed by a variety of stakeholders are typically transformed into a description of a subject matter domain, such as the Boy Scouts' program for knot tying, grade six math, or a training program like repairing a telephone. The general description of what is to be included in this *subject matter domain* is based on these value-laden goals, but a more detailed specification of what capabilities should be included can be provided by professionals through the technical part of the curriculum. Obviously, the distinctions between the value-laden and technical aspects of the curriculum are not clear cut or for that matter usually even recognized in conventional curriculum design. Also, the roles of the lay stakeholders and the professional educators or subject matter experts are not clearly defined or recognized. However, regardless of the makeup of the group or the particular roles of various participants, the result is some sort of description of the content of the course or program.

I call the product of this process the *subject matter domain*. It is a definition of what should be included created by a combination of outside lay stakeholders and knowledgeable individuals in the particular domain. The subject matter domain defines the capabilities that are expected to reside in the students upon completion of an instructional program.

The purpose of identifying this concept of a subject matter domain is to point out the difference between this *stakeholders* vision of curriculum and the much more specific representation of the same domain by held by *experts* within that domain. This distinction is important because it is the value-laden vision of the stakeholders that drives the educational process and should be the reason the educational program exists. It reflects the ideas that individuals or groups from outside the educational or training community think should be learned.

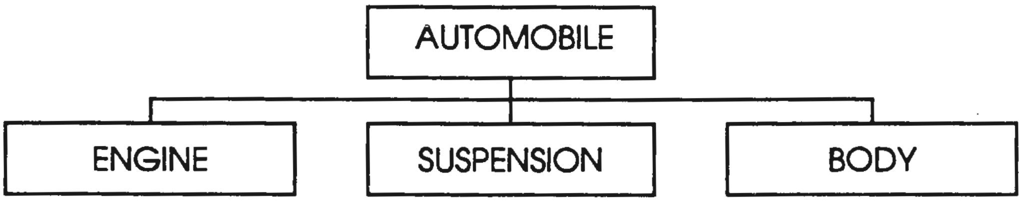
This subject matter domain does not usually consider the gap which might exist between the capabilities the stakeholders deem necessary and the capabilities that the prospective students already possess. Rather, it defines the territory of the domain which the students are all expected to end up with. It also does not usually specify in precise or technical terms the details of the domain. It is left up to subject matter experts to provide this more detailed specification.

A distinction must be made here between representations of subject matter for the purpose of describing or making sense of *the content itself*, and representations that are created for the purpose of designing instruction which will *unfold that content* in a readily learnable fashion for students. Both the value-laden curriculum and the subject matter domains discussed in this section are knowledge representations that do not consider structure or organization from the perspective of designing instruction. I will elaborate on the instructional concerns with subject matter organization in a later section.

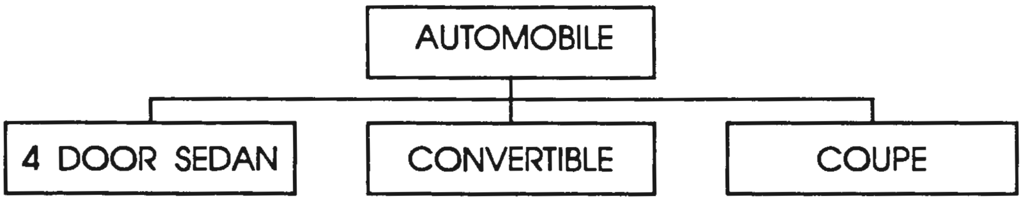
3.19 EXPERTS' KNOWLEDGE REPRESENTATIONS

I call the detailed and specific definition of the subject matter domain an *experts' model* to distinguish it from the subject matter domain envisioned by the stakeholders. The experts' model is devised by experts (of some sort) to provide a complete and detailed specification of what should be included in the curriculum. These experts could be teachers, outside subject matter experts (SMEs), curriculum committees composed of educators from the field, managers, or practitioners. From wherever they come, however, some group has to describe in more detail the nitty gritty of a curriculum. This is the *experts' model* that is based on the subject matter domain described by the stakeholders, and is intended to be an appropriate experts' vision of the domain: complete, detailed, and often complex.[29]

The experts' model is often derived from some sort of hierarchical structure that represents an expert's conceptualization of the domain. Often this hierarchy is based on conceptual organization, either a parts-of or a kinds-of hierarchy. An example of a parts-of hierarchy is this representation of automobiles:



A kinds-of hierarchy representing automobiles would look like this:



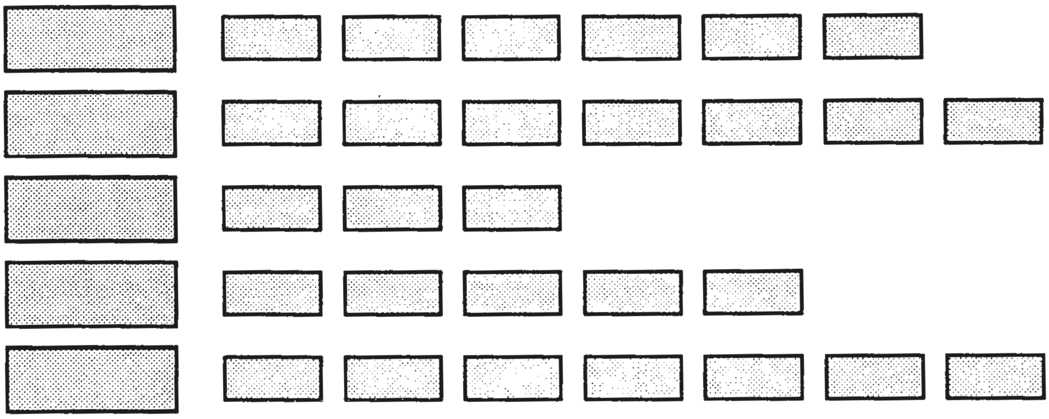
These representations imply, but do not specify, the kinds of relationships among the boxes in the hierarchy. By convention, the upper levels are normally assumed to be more general categories, while the lower levels represent progressively more specific categories.

29 Once again, this is a domain representation rather than an instructional representation of subject matter.

3.20 DACUM Charts

One example of a formalized methodology for creating an experts' representation of a curriculum can be illustrated by the DACUM process.[30] DACUM is an acronym for **D**evelop **A CU**rriculu**M**, and is a procedure for defining the competencies that are required by beginning practitioners in an occupation. For the "to-do" part of the curriculum, DACUM facilitators assemble a group of practitioners who describe in detail what they do in their job. These job-related tasks are listed in a Curriculum Skills Profile, which is a graphical representation of the tasks which comprise the occupation, and is an example of what I call an experts' model. This process is used to partition the curriculum into pieces that make sense to practitioners. However, this partitioning is done in isolation from any instructional concerns. The development of a particular set of courses from the curriculum profile is specifically excluded from consideration in the DACUM process. In addition, the focus in the DACUM process, due partially to its roots in competency based education, is almost totally on the training "to-do" domain. The "to-know" and "to-be" domains are largely ignored, and in most cases, purposefully omitted from DACUM curricula.

The DACUM process results in a conceptual chart that is similar in meaning to a conceptual hierarchy like the examples on the previous page, but represented in a horizontal format, with only two levels:



The column of boxes on the left represent general job categories, while the rows of smaller boxes stretching to the right represent individual competencies required in an occupation. Once again, this chart contains specific information about the concepts in each box, but only implies the relationships among the boxes. In a DACUM chart, the rows of boxes are sometimes arranged either in decreasing order of importance or in a sequence representing the order of the steps in a procedure, but this consideration is not a major concern in the DACUM process. The chart does not provide information which specifies which of these or any of a multitude of other sequences are represented. Once again we have lots of meatballs, but little spaghetti.

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30 Nolan, *The DACUM process.*

3.21 EXPERTS' MODELS

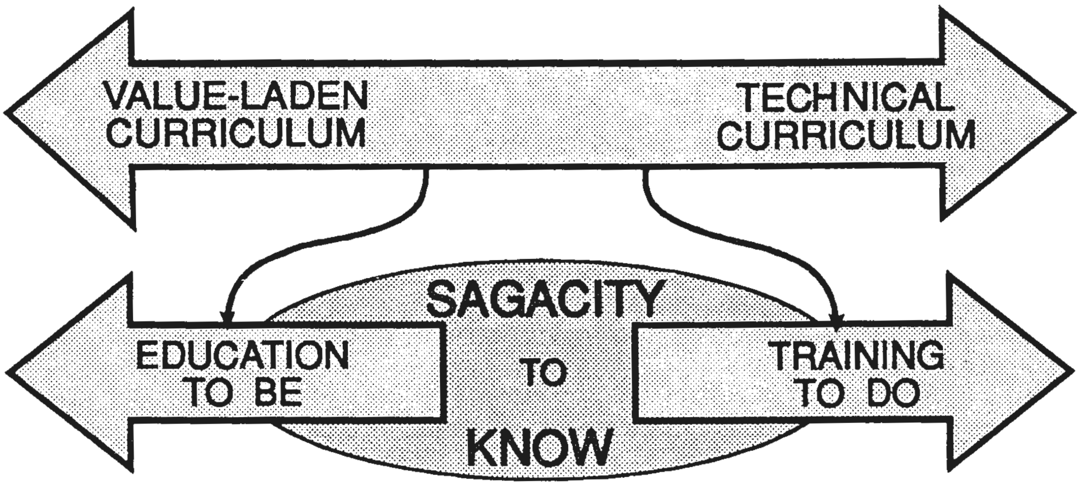
There are some fundamental differences between knowledge engineering ideas for developing *models of domains* and ideas for *instructional sequences.* The experts' model is designed to be a complete description of the subject matter area. It can be a highly organized, rational, rigid structure characterized by complex relationships and great detail. The goal of this kind of model is to provide a complete and comprehensive representation of the domain. The topics are numerous, detailed, specific, and sometimes difficult to understand.

The problem with this, from an educational point of view, is that it might not be the most appropriate representation to use as a foundation for learning. This is based on two concerns. First, the representation may be too complex, detailed, and specific to be teachable to naive learners. Second, the way the subject matter is structured, while it may be an appropriate representation from an expert's perspective, may not be optimal for designing learning experiences. Assuming that these hierarchies are intended as a database for the construction of an educational course or program, they are usually transformed into a representation that is more valuable in defining the scope and sequence of topics or lessons. The format of this educational representation is also usually hierarchical, but often in the form of an outline or a manual such as a program of studies or curriculum guide.

In Part Six: Course Building, some methods of transforming the experts' model into a *curriculum map* more appropriate for the development of learning experiences will be discussed.

3.22 SYNTHESIZER

In this chapter, I have defined the value-laden and the technical curriculum, and suggested that the way these two parts of the curriculum are derived are quite different. The value-laden curriculum is the result of notions of worth held by external stakeholders, while the technical curriculum is created by educators to enable the students to achieve the value-laden goals. I have also suggested that the Three Souls proposition can be used as a tool for analyzing the nature of the value-laden goals and the more technical objectives.



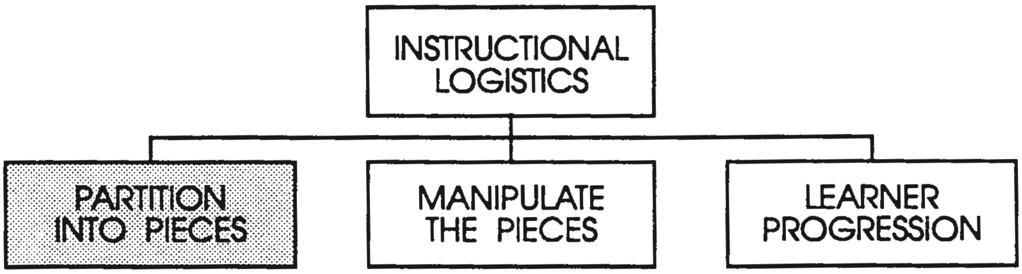
A distinction was made between domain representations, which present a model of some body of knowledge intended to provide a picture of the domain from the perspective of a person knowledgeable in the domain, and an instructional representation of the same domain, which is intended to represent the domain in a manner which makes it easy for a novice learner to comprehend.

The ways in which the subject matter (or knowledge domain) which comprises the curriculum can be represented was introduced in a superficial way, and some of the problems this experts' representation causes for education were noted. Later, several ways in which this expert's representation can be transformed into a more teachable model of the domain will be discussed at length. In Chunque-based learning systems, this educators' representation of a subject matter curriculum is called a *curriculum map*. But first, let us look at how to partition the curriculum into pieces that can assist the learning system designer to create an appropriate curriculum map. What should the pieces be like? On what should they be based? We will explore these questions in Part Four.

PART FOUR: PARTITIONING THE CURRICULUM

4.1 INTRODUCTION TO PARTITIONING

The design of the instructional logistics part of a learning system is based on dividing the curriculum into meaningful and manageable pieces, manipulating those pieces to create an optimal set of learning experiences for each learner, and controlling the progression of the learner through those pieces.



In Part Three we looked at how to decide what should be included in a curriculum map, and at the Three Souls proposition, which defined three different kinds of curricular goals. In creating an optimal learning system to make the curriculum more teachable, one of the first problems to be faced by a designer is determining how to partition the curriculum into meaningful and manageable pieces within the context of the particular learners and intentions. As the whole point of learning system design is the creation of customized learning experiences by assembling small clusters of ideas, the curriculum must be partitioned into pieces that will *make sense to the learner.*

Also, these pieces must be manipulated to create an optimal set of learning experiences for each learner by picking and choosing appropriate pieces. The way in which these pieces are arranged and sequenced will vary from learner to learner. For this reason, each of the pieces should ideally form a self contained unit of content.

This section will look at how large the pieces should be, and explore some of the different strategies that can be used to determine an optimal way of dividing a curriculum into meaningful pieces for different circumstances.

4.2 WHAT ARE THE PIECES BASED ON?

Curriculum specialists have been dividing curricula into units, modules, courses, or lessons since time began. Often, the decisions which determine partitioning of the curriculum are based on the amount of time needed to cover some subject matter. For example, the content of a course is divided into pieces based on an estimate of the length of time it will take to present the content. Lessons are designed to be one period long, or units are created that last for a quarter of the total time allocated for a course. If the timetable changes, the basic unit of content changes. Related to this is the Carnegie Unit principle, which assumes that achievement is related to time spent in a class. One hundred and twenty five contact hours might be considered equal to five credits of achievement. The problem with these divisions is that they are based more on administrative concerns than on any particular characteristics of the subject matter which is to be learned. The partitioning decisions are teacher centered or institution centered rather than learner centered.

Since a fundamental assumption in the design of learning systems is the Triple E proposition that decisions affecting the efficiency, effectiveness, and appeal of instruction should be student centered, the basis of partitioning a curriculum into pieces should be that the pieces are *meaningful to the students* rather than meaningful to experts or convenient for the administration. The basic assumption underlying partitioning in this vision of instructional logistics is that the partitioning of the curriculum into appropriate pieces be based on the characteristics of the ideas in the curriculum. This relates directly to the notion that identification of a basic meaningful piece of content rests on identifying which cluster of curricular ideas constitutes the smallest meaningful piece to a learner.

In addition, one of the cardinal principles of learning system design is criterion referenced assessment, where determination of student accomplishments is based on an assessment of their mastery of the ideas in a curriculum, rather than on credit for time spent in a classroom. This principle stipulates that learning experiences be derived from an analysis of the notions which make up the curriculum rather than from convenient units of time.

This idea of partitioning the curriculum into meaningful pieces is central to the development of learning systems, and a crucial aspect of instructional logistics.

4.3 BLOOM'S VIEWS ON PARTITIONING

In considering alternatives to typical time-based curricular units, there has been considerable discussion over just how large a unit should be. From the perspective of curriculum design, Bloom suggested in 1976 that:

> ... it is necessary to relate the learning and instruction to a smaller unit than an entire course or curriculum. This basic unit may be a learning activity, a learning project, a learning task, or some other way of conceiving of an interaction between a *learner, something to be learned*, and a *teacher* or *tutor*.[1]

Bloom concluded that:

> The learning unit selected should be applicable to school learning situations which are individualized as well as those which are group based with most of the learners expected to learn many of the same things at the same time.[2]

These notions from Bloom were fundamental in developing his mastery learning strategies, which are an essential component of learning systems as proposed here.[3] Bloom's reason for suggesting smaller units of analysis are summed up in this passage regarding the difficulty in assessing what happens and why it happens over longer periods of schooling:

> But the dimensions of this are so great that we can do little more than report on these differences and attempt to account for them by the use of intelligence and aptitude variables, personality and motivational variables, school variables, and home variables. Even when we have accounted for a large portion of this variation, we are left with the feeling that while we have done the right bookkeeping, there is little that we can do to change the conditions for the next generation of students.[4]

Bloom was concerned that if the unit of analysis was too large, it would be hard to determine in a descriptive sense what was happening in the classroom, and in a prescriptive sense, it would be very difficult to prescribe optimal methods that would apply across such a large unit of instruction.

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1 Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill. (p. 22).

2 Bloom, *Human characteristics*, (p. 20).

3 The application of these strategies will be discussed in Part Nine, Micro Logistic Strategies.

4 Bloom, *Human characteristics*, (p. 19).

4.4 THE REDUCTIONIST PROBLEM

Merrill, Li, and Jones[5] note that the design of learning experiences from the perspective of the instructional designer is centered on a much more reductionist view of subject matter. The behaviorist roots of systematic instructional design I mentioned earlier tend to focus attention on the smallest units of content. In explaining the shortcomings of what they call *first generation instructional design*, Merrill suggests that more global models are needed, and a different and larger unit of analysis is required. He identifies the micro-focus on small pieces of content and prescriptions for teaching them as one of the shortcomings with current instructional design models and prescriptions.

Merrill's original Component Display Theory propositions were based on prescriptions for single ideas, the level which Reigeluth calls micro-level strategies.[6] Recently, Merrill has stated that micro-level strategies might be more useful in the design of learning experiences if they were to address *clusters* of ideas rather than single notions.[7]

Baker, in exploring the potential of computer managed learning in 1978, also rejected the reductionist view which he characterized as a unit of analysis based on a single behavioral objective. Baker urged that upward integration be stressed, with more attention paid to higher level goals rather than the ideas related to individual behavioral objectives.

Bloom also considered much smaller units of analysis, suggesting that "it might be desirable to move to an atomistic level were each interaction of student, teacher, and material can be recorded and related to every other interaction ...,"[8] but chose instead to work with "a somewhat larger or molar unit."[9] Bloom settled on:

> a unit that has some relevance for the ways in which school learning is organized, the ways in which most students and teachers confront existing learning situations, and the curriculum and learning material with which they work.[10]

Perspectives on the size and nature of a unit of subject matter such as these suggested by Bloom, Baker, and Merrill, Li, and Jones form the basis of partitioning the curriculum in instructional logistics. The final means of determining how to proceed is an extension of Bloom's choice of unit of analysis.

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5 Merrill, M. D., Li, Z., & Jones, M. K. (1990). Limitations of first generation instructional design. *Educational Technology, 30* (1), 7-11.

6 See Reigeluth, C. M. (1983a). Instructional design: what is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates for an explanation of Reigeluth's micro and macro level strategies.

7 This is from a conversation with Merrill in 1988 regarding some tentative explorations of what the pieces should look like.

8 Bloom, *Human characteristics,* (p. 21).

9 Bloom, *Human characteristics,* (p. 22).

10 Bloom, *Human characteristics,* (p. 20).

4.5 BLOOM'S CHOICE

Bloom decided that the most appropriately sized piece of curriculum for dealing with his mastery learning strategies could be defined like this:

> The unit that we believe is the most relevant for our purposes is a *learning task* comprising what is usually referred to as a learning unit in a course, a chapter in a textbook, or a topic in a course or curriculum. ... Defined in this way, a learning task may include a variety of subject matter or content elements as well as a variety of behavioral or learning process elements. The point of all this is that this type of unit contains a variety of ideas, procedures, or behaviors to be learned over a relatively short period of time.[11]

This sounds a lot like the mental models of Minsky and Norman. Let me review Part Two. One function of mental models, according to Norman,[12] is to allow our minds to overcome the limitations of short term memory by uniting a bunch of independent notions into a single unit. To "thingify" a cluster of ideas. Minsky again:

> Whenever an agency [in our mind] becomes overburdened by a large and complicated structure, we may be able to treat that structure as a simple, single unit by thingifying - or as we usually say - conceptualizing it... This way we can build grand structures of ideas...[13]

We build these out of clusters of related ideas. A mental model is used, in this sense, to provide a tool for understanding. In computerese, it resembles a macro.

I believe that we can use these notions from the curriculum development field and the domain of artificial intelligence and computer interface design to develop useful principles to guide the partitioning of a curriculum in a way that will provide meaningful units of subject matter for our students.

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11 Bloom, *Human characteristics,* (p. 22).

12 Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books.

13 Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster, (p. 231). These grand structures are what we are after. This mechanism looks somewhat like a parts-to-whole sequence.

4.6 CHUNQUES

What constitutes an appropriate cluster of ideas to foster the meaningful understandings discussed in Part Two? What should our unit of analysis be? Minsky proposes that a mind develops layers of meanings and interconnecting links until the cluster "acquires some useful and substantial skill." It then "tends to stop learning and changing, and another layer can begin to learn and exploit the capabilities of the last."[14] This network of related ideas may be the smallest unit of content that has value and meaning in it's own right. I call it a *chunque.*[15]

A chunque consists of a collection of ideas (like facts, concepts, procedures, and principles) and their relationships which combine to represent a minimal unit of understanding; a useful and substantial collection of notions. It is the cluster of ideas that we use to express and address our intentions.[16] Understanding is an internal characteristic of a chunque. "We are always chopping complex structures into artificially clear-cut chunks,[17] which we perceive as separate things."[18] When one chunque of understanding is placed in context with other chunques and cross-linked to other realms of understanding to form a referential network, the result is what Pagels calls *meaning*, the external characteristic of understanding.[19] Within-chunque ideas and relationships provide understanding. Among-chunque linkages provide meaning. A combination of the two provide meaningful understandings. As we shall see in a while, within-chunque ideas and links are the stuff of micro-logistic strategies: among-chunque contextual links comprise the domain of macro-logistic strategies.[20]

Over the next few pages, this notion of a chunque will be expanded by relating it to a number of other ideas regarding the principles upon which to base the partitioning of a curriculum.

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14 Minsky, *The society of mind,* (p. 92).

15 I coined this word to avoid confusion with a multitude of other terms such as unit, module, chunk, and so on that have a variety of meanings (contextual referents?) so broad as to confound the issue. It is a bilingual Canadian word which is pronounced similarly to "cheque", the Canadian equivalent to what Americans cash at banks (banques?) Chunque is pronounced chunk. Some Canadians pronounce it chunn-cue, similar to kung-foo.

16 House, E. R., Mathison, S., & McTaggart, R. (1989). Validity and teacher inference. *Educational researcher, 18* (7), 11-15, 26.

17 Note that Minsky spells this "chunk", which is a more general term for a piece of something than my term *chunque* which specifically refers to the pieces of subject matter explained here.

18 Minsky, *The society on mind,* (p. 232).

19 Pagels, H. R. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity.* New York: Simon and Schuster.

20 Reigeluth, *Instructional design: What is it.*

4.7 KNOWLEDGE REPRESENTATION VERSUS INSTRUCTIONAL REPRESENTATION

There is a fundamental difference between representing an area of subject matter for the purpose of defining the notions a curriculum consists of and defining the same area of subject matter in a way which might aid in structuring a collection of learning experiences to unfold that subject matter to students. There is also a difference between representing a knowledge domain and representing only those parts of the domain that will be included in a curriculum for some sort of educational program.

Knowledge engineering is a field that in concerned with representing some area of human understanding (a knowledge domain) that explains how an expert views the domain. The product of knowledge engineering is a *knowledge representation* that can be in the form of a hierarchy like the simplified part-of or kinds-of conceptual hierarchies illustrated in Section 3.19, or in the form of a relational network as in Sections 2.9 and 2.10, or as a cognitive map like the one in Section 1.7 that represents learning systems design. Regardless of how a knowledge domain is represented, the point is to make sense of the domain from the perspective of an expert. A knowledge representation does not consider how to teach someone about the domain.

A *DACUM chart* is a means of representing a knowledge domain for a particular occupation from the perspective of an expert practitioner. It also does not consider how to teach the domain to a student. But it does consider what parts of the knowledge domain should be included in an instructional program to prepare people for the occupation. Therefore, it is a restricted form of knowledge representation that includes only those things that a beginning practitioner should be able to do. As noted in Part Three, this representation is what I call a *curriculum map*, a particular kind of knowledge representation that makes sense of the notions that should be included in the curriculum for an educational program but does not consider the sequencing or structuring of learning experiences.

An *instructional representation,* on the other hand, is a representation of a knowledge domain that is intended to organize the notions in a curriculum map (a special kind of knowledge representation) in a way that both makes sense of the domain and defines how to organize those notions in a way that makes learning as easy as possible. The intention in creating an instructional representation is both to illustrate the subject matter in the curriculum and how to unfold the subject matter to a novice learner.[21]

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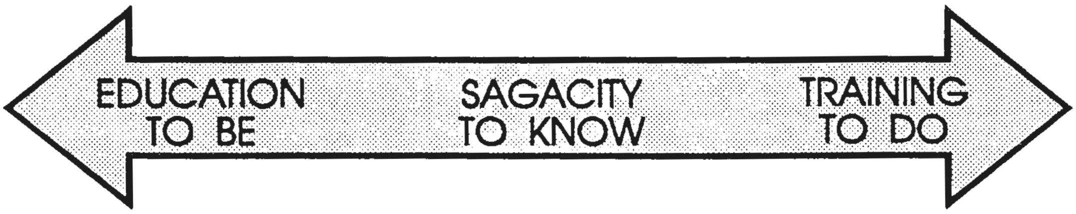
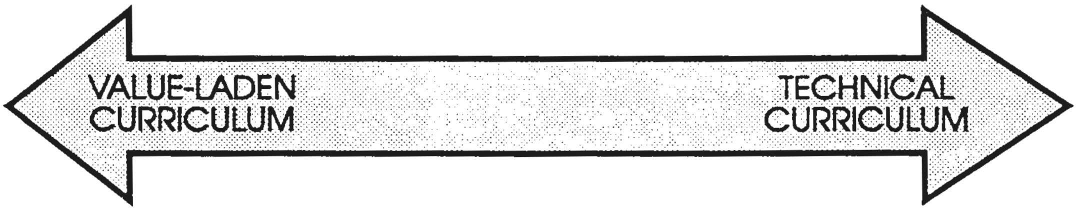
21 A distinction must be made between a naive learner, a novice learner, and an expert. A naive learner is one who has no experience in the field. A novice learner is one who has limited experience with the field or material being investigated. An expert is one who has had extensive experience and is very familiar with the field. See Shuell, T. J. (1990). Phases of meaningful learning. *Review of Educational Research. 60* (4), 531-547.

4.8 CURRICULUM CONTINUA

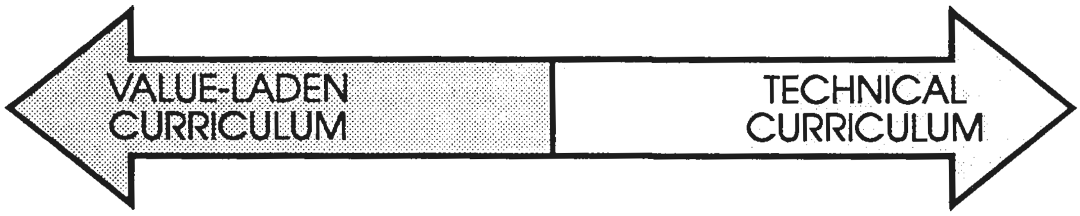
In Part Two the idea of representing curriculum as a continuum from value-laden concerns to technical concerns was introduced. This notion proposes that in this kind of curriculum continuum, there are ideas included because they are valued, and other ideas included because they are necessary to represent the valued ideas to the learners. There are also Education-to-Be and Sagacity-to-Know and Training-to-Do ideas, which can be represented on a different kind of continuum.



Partitioning the curriculum should be related to the characteristics of these ideas. I maintain that the basic unit of content can be identified from an analysis of the characteristics of these ideas and their interrelationships. Let's explore the range of ideas that comprise a curriculum viewed as lying along a continuum with ideas based on value-laden significance at one end blending gradually into ideas required by technical instructional considerations at the other.



For the purpose of designing a learning system, it might be more productive to view these two types of curricular ideas as dichotomous. The dividing line between the two kinds of curriculum is the point where the value-laden curriculum ends and the technical curriculum begins. This can also be envisioned as the point at which details of the content lose much of their significance in a global view of the goals of the program.



The Chunque Theory proposes that one way the point of dichotomy can be defined is the point at which curriculum committees lose interest, the point where value-laden ideas are replaced by technical ideas. Another way this point can be defined is the point where curricular ideas cease to have intrinsic value in their own right and become necessary supporting ideas.

4.9 THE CURRICULUM CONTINUUM PROPOSITION

One significance aspect of the dividing line between the value-laden and technical curriculum is that it allows us to identify the basic unit of content, the chunque, based on the characteristics of the ideas in the curriculum, the goals and objectives of the stakeholders, and the needs of the learner. A learning experience designed to teach this smallest cluster of valued notions is what I call a *primary Chunque* of instruction.[22]

> THE CURRICULUM CONTINUUM PROPOSITION
>
> In order to devise a method for partitioning the curriculum into meaningful pieces, it is necessary to determine the characteristics of the ideas in a curriculum. I believe that there are two distinct kinds of curriculum, a value-laden curriculum, which is grounded in notions of societal worth, and a technical curriculum, which is determined by identifying those ideas necessary and sufficient to obtain the goals of the value-laden curriculum. I believe that, although the value-laden and technical curricula can be ranged along a continuum, for practical purposes this continuum can be viewed as dichotomous. The dividing point in this dichotomy can be defined as that point at which society ceases to be concerned with the details of the curriculum, and at which technical decisions must be made to enable the learner to reach the societal goals.

Remember the DACUM chart? The vertical column of boxes at the left of a DACUM chart represent categories or clusters of capabilities that competent practitioners feel the students should have. Each box in the horizontal rows (bands) of boxes represent one competency (or set of capabilities) that the students are expected to have when they leave the program. I think each box in a row is the bottom of the *value-laden* part of the curriculum.

What is inside each of the boxes represents the more technical part of the curriculum. The stakeholders (the competent practitioners on the DACUM committee) deal with curriculum competencies down to the level of the individual boxes. The boxes are the focus of the practitioner's vision of the domain. Each box, which is the lowest level of the value-laden curriculum, is a chunque of subject matter. The mix and match learning system mentioned in Part One would do the mixing and matching at the chunque level.

Thus, by this definition, a Chunque (of instruction) relates to the smallest meaningful piece of content defined as worthwhile in its own right by practitioners.

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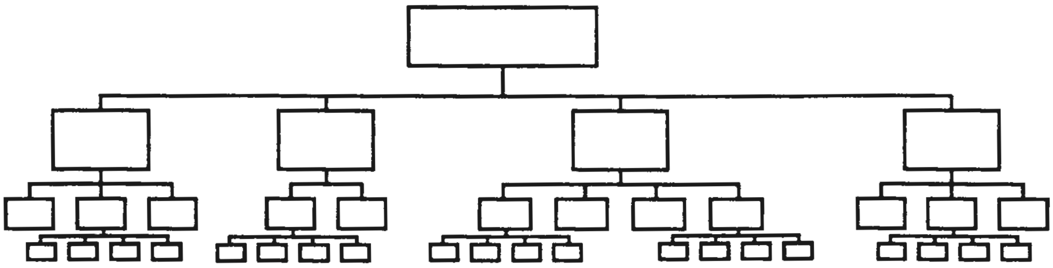
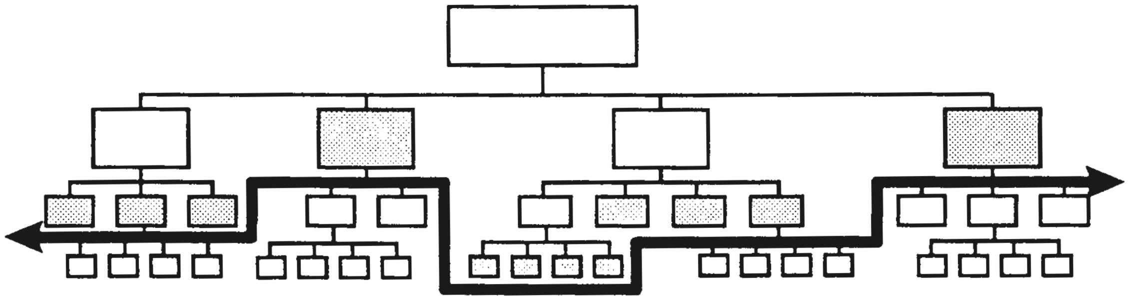
22 Chunques were discovered in a donut shop in Calgary early one morning while Janet McCracken and I were trying to figure out the optimal size of Merrill's *unit of analysis*. I still have this conversation on tape, and use it as an example of eclectic theory construction and compulsive donut consumption.

4.10 CONCEPTUAL HIERARCHIES

If a knowledge domain is represented as a multi-level conceptual hierarchy, it might look something like this:[23]



Applying the curriculum continuum proposition to this collection of topics (not chunques) will result in a dividing line between the value-laden curriculum and the technical curriculum. At some level, the value-laden notions of outside stakeholders will give way to the nitty gritty technical notions of educational professionals The line might not lie straight across the hierarchy at one level:



Any box directly above the dividing line represents the smallest *chunque* of subject matter. These boxes, shown shaded in the above figure, represent the lowest level of value-laden notions. This level is the level of detail that is of interest to the stakeholders. Anything above that level represents notions that synthesize the chunque-level notions into more global meanings. Anything below that level represents more technical notions that provide more detailed understanding of the chunque-level notions. In this sense, the term *chunque* refers to a collection of topics or ideas. However, in instructional logistics, the term *chunque* can also refer to the learning experiences that are used to teach this chunque of subject matter. In this usage, the term will be capitalized, as in a *Chunque* of instruction.

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[23] Note again that the characteristics of the links in this hierarchy are not defined by the diagram. We are left to imply that the upper boxes represent more general concepts and the lower boxes more specific concepts. Thus we can deduce that this hierarchy ranges from general at the top to specific at the bottom.

4.11 THE BOY SCOUTS REVISITED

To illustrate the distinction between the value-laden curriculum and the technical curriculum, consider the Boy Scout example we looked at earlier. The stakeholder's committee determined that knot tying was a worthy activity to include in the curriculum, but they were not too interested in the details of what had to be learned in order to tie the knots. To have the capability to tie the knots was the smallest piece of content that the stakeholders were interested in. They were happy to leave the details up to the educators.

The stakeholders might reasonably be expected to be concerned with selecting which particular knots would be included in the program. At the same time, they would not likely be concerned with the more technical decisions regarding an analysis and selection of just what ideas must be understood or manipulations performed by the learners in order to ensure that they can tie the knots.

In this example, tying the knot is the smallest piece of content that is meaningful to the stakeholders. Anything below the level of a knot is relatively meaningless as a valued skill or capability. This illustrates the notion that the dividing line between the value-laden and technical curriculum can be defined as the point where the stakeholders tend to lose interest.

Another example of the basic unit of content could be found in Sunday School lessons. Sunday School students often receive gold stars in a booklet whenever they succeed in mastering some piece of the curriculum, such as memorizing the Lord's Prayer or the Ten Commandments. The Gold Stars are awarded for completing a basic unit of content. Not many Sunday School students receive a Star for learning one Commandment.

Similarly, in the Boy Scout example, the tying of one kind of knot could be defined as the smallest piece of content which has significance to the stakeholders. In the Sunday School example, the Gold Stars are awarded for the smallest piece of content for which recognition of achievement can be granted. In different ways, both of these examples illustrate that the basic unit of content is also related to the smallest achievement that either has intrinsic worth to the stakeholders or is a meaningful achievement for the learner.

4.12 THE SIGNIFICANCE OF THE CHUNQUE

There are several characteristics of the chunque that relate to the ideas of goals and curriculum continua discussed in the previous sections. As we saw earlier in the discussion about mental models, the chunque also appears to be a cluster of ideas that forms a complete mental model or sort of self-contained conceptualization in the mind of the learner. This notion that our mental models are what we use to "thingify" ideas into understandable units is a compelling notion for the partitioning of subject matter, and becomes even more so when the same sort of "chunks" appear to have much in common with the other partitioning propositions discussed here. We have seen that the chunque can be described as a cluster of ideas that is meaningful in its own right, and because of this, it would seem reasonable to consider the chunque also as the smallest cluster of ideas for which certification of mastery should be granted. This ties in closely with Bloom's *learning task* units, which mastery learning strategies propose as optimal units of content for certification of mastery.[24]

Decisions regarding which chunques to include are the ultimate responsibility of lay stakeholders; decisions regarding the organization and presentation of ideas within a Chunque are of more interest to instructional professionals. Notice also that the size of a chunque of subject matter is both a value-laden curricular idea and a technical idea, while the makeup of a Chunque of instruction is considered here to be primarily (and perhaps almost exclusively) a technical concern.

In the previous sections, a set of Chunques (of instruction) that form the bottom level of the value-laden curriculum were described, and the suggestion was made that these *primary* Chunques form the level of interest to outside stakeholders. The notions represented by boxes below this level comprise the ideas that make up the internal learning experiences which reside within the Chunques. The notions represented by boxes lying above this bottom level of the value-laden curriculum comprise a set of integrating and synthesizing notions which tie the *primary* chunque-level notions together into a more cohesive whole. The learning experiences for synthesizing notions represented by these higher level boxes are called *synthesizing* Chunques. These higher level Chunques contain primarily linking notions to tie the ideas together.

The primary Chunque level can be seen to sort of slide up and down within a hierarchy representing a domain depending on the intention of the stakeholders. For example, in a DACUM chart for our Western Horsemanship program, one of the primary level Chunques is for the capability to "operate a bobcat." Just what comprises operating a bobcat is left to the faculty to decide: the stakeholders stopped at the level of "operate a bobcat." In another program for equipment operators, an entire course (or learning system) could be provided just for operating a bobcat. In this case, the particular capabilities identified by competent equipment operators could lie at a much more specific level, and the primary Chunque would slide down to a much more detailed description of particular capabilities, such as "drive the machine" or "use the bucket to level a lawn."

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24 Bloom, *Human characteristics.*

4.13 CHUNQUES AND THE DACUM PROCESS

The DACUM process, by its very nature, defines the primary Chunques based on the dividing line between the value-laden and technical curriculum. This split defines, in the eyes of the particular stakeholders (practitioners) what a "useful and substantial" collection of notions is within the context of the job or occupation. The DACUM process defines *both* the particular competencies and the level of detail that they see as appropriate for beginning practitioners. These definitions specify the primary Chunques.

This is a partial answer to the problem of the primary Chunques sliding up and down within a hierarchy that represents a knowledge domain: the level is defined by the stakeholders. One powerful outcome of the DACUM process is this method of converting, if you will, a multi-layered hierarchy of ideas which comprise a knowledge structure (an expert's model of a domain) into a representation appropriate for developing a course targeted at particular learners. The capabilities specified by stakeholders in a subject matter domain and elaborated into a complex and detailed knowledge structure by domain experts[25] is transformed into a representation anchored to the goals of a specific program.

This result can, of course, be produced by other procedures, but the DACUM method seems to be especially useful to tease out both the capabilities and the level of detail.

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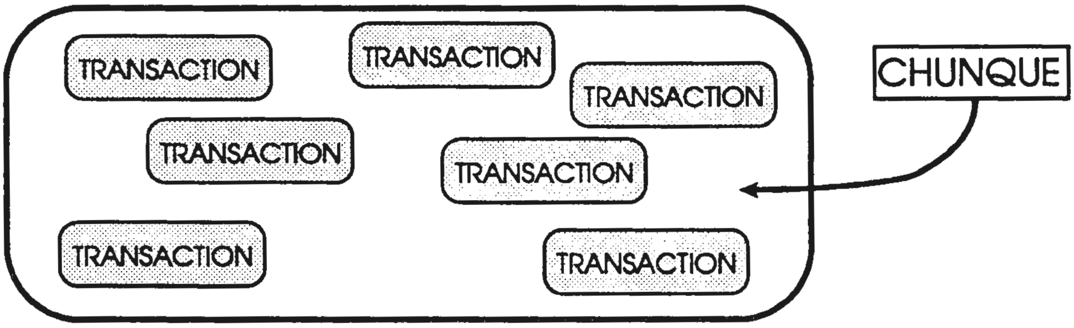
25 See Sections 3.18 and 3.19 for a discussion of these representations.

4.14 THE CHUNQUE REVISITED

The cluster of ideas that comprise a chunque are the basic unit of content in a learning system. The chunques are identified based on characteristics of the ideas in a curriculum continuum. The cluster of ideas included in a chunque is determined by the dividing line between the value-laden and the technical curriculum, not by the number of ideas to be included or by an estimate of the time it might take a learner to complete the instructional program for a chunque. The ideas, not time estimates, are important in the development of learning systems because a fundamental assumption is that a learning system is a student centered method of developing a learning environment.

Dividing curricular ideas into chunques is also of benefit when describing a program to lay stakeholders. If the discussion is limited to the level of the chunque, the cluster of ideas comprising the chunque will be both significant and valuable in terms of program goals. Chunques of instruction are comprised of smaller pieces of instruction called transactions.[26] Merrill defines a transaction as a piece of instruction for a single idea. There are different types of transactions for concept attainment, problem solving, verbatim recall, and a host of other classes of instructional ideas. The composition of the transactions within a Chunque will be discussed at length in Part Nine, Micro Logistics Strategies.



An ordered collection of Chunques can be combined to form a course. The path of a learner through a collection of Chunques can be manipulated to create an optimal set of learning experiences for that learner.

A Chunque is an ordered collection of transactions for a cluster of ideas and relationships which together comprise a mental model of knowledge deemed to have value in its own right. A (primary) chunque is the smallest piece of content within a learning system for which certification can be granted.

[26] Merrill, M. D. (1988). An expert system for instructional design. *IEEE expert*, Summer, 25-37.

4.15 MACRO-LOGISTICS AND MICRO LOGISTICS

When dealing with instructional logistics, I call the domain above the value-laden/technical dividing line *macro-logistics*, and the domain below this line *micro-logistics*.[27] This terminology is patterned after that used by Reigeluth in the *Green Book*.[28] Macro-logistics is concerned with manipulating Chunques to create optimal programs. Macro-logistics deals with the organization and selection of meaningful pieces of content. Micro-logistics is concerned with selecting and manipulating transactions within Chunques to create optimal learning experiences. Micro-logistics deals with achieving mastery of a cluster of ideas that comprise a meaningful chunque.

A basic assumption of the Chunque Theory is that fundamentally different instructional strategies must be used at the macro-logistics level and at the micro level. Different things happen within Chunques than happen between Chunques. At the macro level our concern is with creating an optimal progression for each learner through a collection of Chunques. These concerns deal primarily with the nature of the links among the Chunques. Our concerns lie in selecting and sequencing clusters of Chunques to create a set of interrelated learning experiences which will suit the characteristics of the learner, the ideas, and the situation. The path through the Chunques supports learning through inter-Chunque meaning, Minsky's cross-realm correspondences.[29]

Within Chunques, the concern is with creating an optimal set of transactions which will permit the learner to form an appropriate representation of the ideas that comprise the Chunque, and to gain *understanding*. Traditionally, this would be seen as focussing primarily on the nodes, but as we have seen, this must include both the nodes and the links. The actual *instruction* resides primarily within the primary, lowest-level Chunques. Our concern is with presenting ideas, evaluating learner understanding, diagnosing and remediating misconceptions, and certifying mastery.

The distinction between macro and micro logistics is a tool to aid in the design of learning systems. It is an artificial distinction, an invention, valued only by its utility and usefulness in aiding the design process. I am not suggesting that this distinction holds up in the design of all curriculum ... only that it might prove helpful in learning system design, where the goal is to devise customized instruction by manipulating stand alone pieces of instruction. In Part Five we will explore the idea of manipulating Chunques to create a customized set of learning experiences for each student. Later, in Part Nine we will come back to look at micro-logistic strategies that can be used to design transactions within a Chunque.

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27 This is directly related to the Reigeluth-Merrill Elaboration Theory concept of macro level instructional design being concerned with design strategies for many ideas, and micro level instructional design being concerned with strategies for a single idea. Recently, Merrill has suggested that micro level instructional design should be concerned with transactions for a few related ideas. This closely matches the idea presented here of the smallest meaningful piece of content. See Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates.

28 See Reigeluth's article *Instructional design: What is it and why is it?* in C. M. Reigeluth (Ed.) *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

29 Minsky, *The society of mind.*

4.16 LEARNING MODULES

In some instances, learning system designers might determine that a Chunque of ideas is too small of a unit to deal with conveniently. As an example, in our Boy Scout knot tying curriculum, dealing with instruction for each individual knot (which would certainly qualify as a Chunque) as a separate entity could be overly reductionist. There would soon be a need for extra large sleeves on the Scouts' uniforms if a merit badge were awarded to certify mastery of each knot.

In situations like this, a number of Chunques can be combined to form a larger and more easily manipulated piece of content. The Chunque Theory defines this as a *learning module*: a meaningful and ordered collection of Chunques combined for administrative or practical reasons.

The Chunque is a *theory based* minimal unit of instruction. The Chunque is a valuable concept for learning system designers, as it allows systematic partitioning of a curriculum. A learning module on the other hand is an administrative device, based on practicalities.

Although a number of Chunques might be combined to create a more practically sized unit of content, a learning module, subdividing Chunques into smaller units of content is not generally acceptable, as there is a danger that the collection of ideas contained in any unit smaller than the Chunque is relatively meaningless to a learner. Minsky[30] stresses the importance of making knowledge meaningful, and relating new ideas contextually with pre-existing ideas. Dealing with pieces of content smaller than a chunque does not appear to support this notion.

It must be emphasized here that there is a distinction between "technical" notions, used by professionals in the course of their work, and transformations of those notions into less technical "consumer" concepts. The notion of a Chunque as a minimal piece of meaningful instruction is a technical notion, the utility of which can be judged by its value in creating optimal learning experiences. The notion of a learning module is a less technical expression of pieces of content that may be more meaningful to learners.

In a similar vein, the statement of rigorous behavioral objectives for each idea (or capability) in a curriculum appears to often be too technical of a notion to impose on learners. A more meaningful, simplified, expression of the notion might be both more meaningful and useful to a learner. We will look at this in Part Eight, Assessment and the Pursuit of Excellence.

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30 Minsky, *The society of mind.*

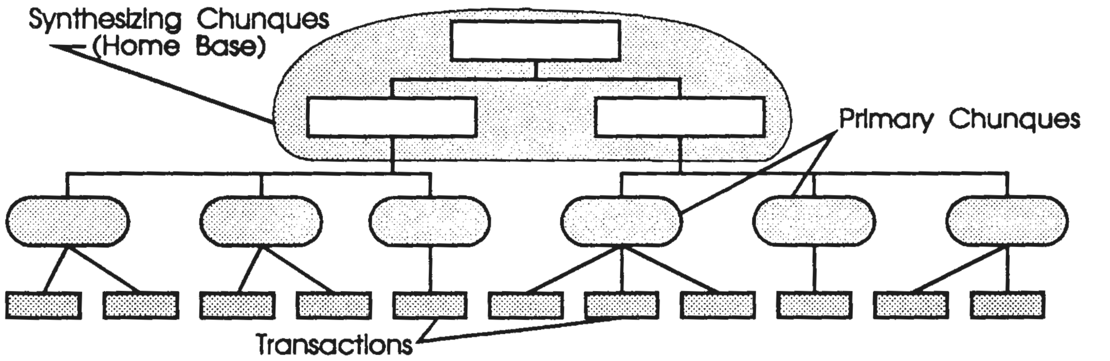
4.17 WHAT DOES THIS GIVE US?

Now we have a set of principles that can be used to partition a curriculum. This partitioning is based on splitting a curriculum continuum into two discrete pieces which I have called the value-laden and the technical curriculum. The result of this partitioning is the chunque, a basic unit of content. These chunques are the pieces that we will manipulate to create an optimal set of learning experiences for each learner.

A distinction was made between Chunques lying just above the dividing line between the value-laden and technical curriculum and higher-level Chunques which are used to synthesize the subject matter and provide contextual meaning. The Chunques lying just above the value-laden/technical split are defined as *primary Chunques*, and are the basic unit of analysis used in designing learning systems. The adjective *primary* will usually be omitted when referring to these Chunques. The Chunques lying above this primary level will be referred to as *synthesizing Chunques* when a distinction is necessary.[31]

Chunques of instruction are theoretically grounded technical entities, primarily of interest to learning system designers. Chunques may be transparent to the learner. Chunques may be combined to form more practically sized units of content, learning modules. Learning modules are of interest to students, and they might be a more appropriate basic unit of content presented to a learner, and the basic unit upon which certification of mastery is granted. Throughout this discussion, we will talk about Chunques rather than learning modules. This is based on three concerns. First, a Chunque is a theoretical entity, while a learning module is a practical entity. Second, whatever instructional strategies can be applied to a Chunque can also be applied to a learning module, and third, the term *learning module* has a wide and varied usage in instructional design and curriculum literature, which could lead to confusion. It is unlikely that anyone will confuse a Chunque with something else.

This diagram illustrates the relationship between some of the parts of a learning system described so far:

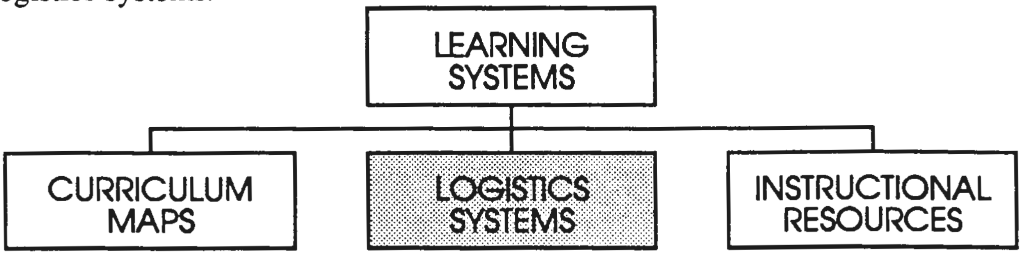


31 In Section 1.16, discussing the PASSPORT learning system, the collection of synthesizing chunques comprised the Home Base, or central scheduling module of the system.

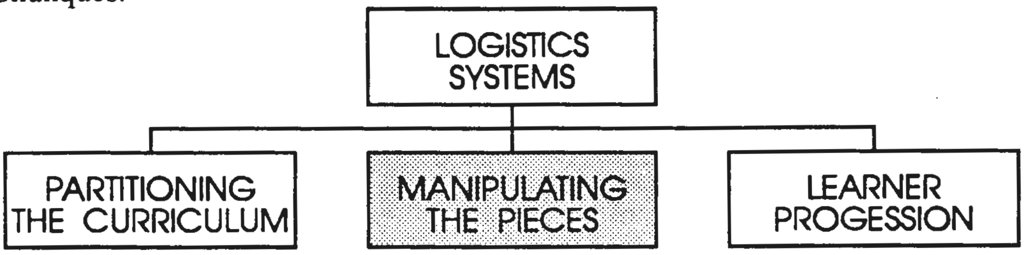
PART FIVE: CUSTOMIZED LEARNING EXPERIENCES

5.1 INSTRUCTIONAL LOGISTICS

Earlier on, I discussed the relationship between learning systems and instructional logistics. Learning systems are comprised of three parts; curriculum maps, logistics systems, and instructional resources. In this section, we will be dealing with the logistics systems.



Logistics systems are dependent upon three activities; partitioning the curriculum into self contained Chunques, manipulating the Chunques to create customized learning experiences, and controlling the progression of the learner through the Chunques.



In the previous sections, a distinction was made between macro-logistics and micro-logistics. Macro-logistics is concerned with between-Chunque strategies while micro-logistics is concerned with within-Chunque strategies. In the sections that follow, the discussion is limited to macro-logistics and the creation of customized paths for the students by selecting and sequencing Chunques. A discussion of micro-logistic, within-Chunque customizing strategies is left for Part Nine. In Part Four partitioning the curriculum into chunques based partly on the notion of mental models was discussed; in this section we will explore ways to manipulate Chunques of instruction to create customized learning experiences.

A number of features characterize many traditional educational programs. Most decisions regarding both what is included (and excluded) from the program, and the sequence of presentation is the same for everyone. Also, the amount of time and other resources allocated is the same for most learners. Bloom calls this "teacher based and teacher paced" education.[1] In other words, there is only one path through the program for all students.[2] The decisions which determine the design of a path are usually made well in advance by the developers of the program, and are both difficult to modify, and out of the control of the learner.

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[1] Bloom, B. S. (1976). *Human characteristics and school learning.* New York: McGraw-Hill. (p. 20).

[2] This is obviously an oversimplification, but the general model for traditional formal education has been lock-stepped group based instruction.

5.2 CUSTOMIZING THE INSTRUCTION

Our ranch is out in the foothills near Banff. In the national park there are an ever expanding number of trails to various scenic spots. Over the last few years, professional designers have been laying out new paths to previously inaccessible parts of the mountains. In most places, there is only one path from the highway or parking lot to the scenic attraction that is of interest to the tourists. This path, like the path through teacher based and teacher paced instruction, is a common denominator path. It is an attempt to create the one most optimal path to accommodate the needs of the widest range of tourists. These paths, in my opinion, are very well designed. But, when I walk along them, I constantly see shortcuts, detours, and meanderings created by the adventuresome hikers that find an attraction that is different from the norm envisioned by the park planners. Perhaps the planners need to consider the possibility of laying out a multitude of paths that all reach the same spot, but are customized to accommodate the needs and wishes of a variety of different people.

These paths could be customized for different reasons. In some cases, they may be customized to account for the different interests of the tourists. One could hit all the meadows for the botanist, another could pass through the trees for the bird watcher, while still another could skirt the bogs and the moose. For me, they should follow the railroad tracks. Other paths might be designed to accommodate our disabled persons, the elderly, or the ironman hiker. These could be designed to meet the physical abilities of the tourist.

One of the cardinal principles of chunque-based learning systems prescribes the creation of different paths for different students, and ideally a different path for each learner. If there exists only one path for all students, then the system should not be defined as a learning system as the term is used here. A learning system must have a number of different paths to suit the needs of different students.

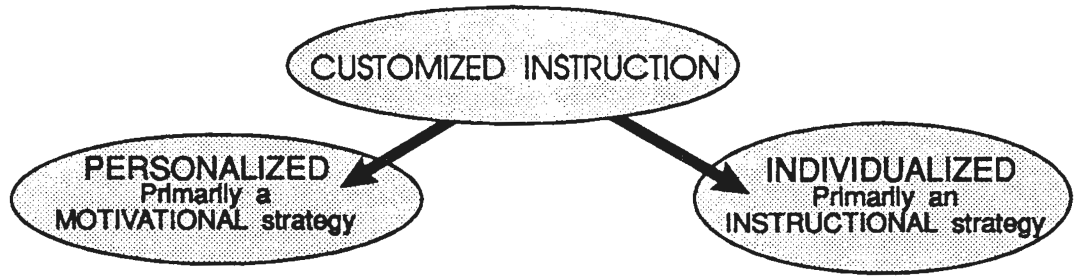
The creation of an optimal path for each particular learner implies that at least some portion of the learning experiences be customized to meet the needs of the learner. In this way, the benefit of the instruction can be maximized for each learner. *Customized* instruction is comprised of a unique set of learning experiences selected and sequenced to suit the characteristics of an individual learner, the ideas in the curriculum, and the circumstances. It should provide optimal efficiency, effectiveness, and appeal for that learner.

5.3 PERSONALIZING AND INDIVIDUALIZING

The notion of customizing instructional programs has been around for a long time. The terms individualized instruction, personalized instruction, and programmed instruction refer in some ways to the same notion of tailoring the instruction to suit the learner.

The notion of customizing the instruction along three dimensions of the Triple E; efficiency, effectiveness, and appeal, has not been widely recognized. The emphasis historically has been on the effectiveness of instruction, which has also been the primary focus of many instructional design theories and models. We need to make a clear distinction between these three dimensions, as the strategies for each are markedly different. If we accept the idea that the creation of optimal sets of learning experiences *from a learner's perspective* requires attention to all three of the Triple E dimensions, then the notion of customized instruction can be divided into two parts.

The first type of customized instruction is *personalized* to suit the desires of the learner, in which case customizing is primarily a motivational strategy. The intention of personalizing is to make the instruction more enticing, and increase its *appeal* (and utility) to the learner. The second type of customized instruction is *individualized* to suit the instructional needs of the learner. In this case there is a range of *instructional* strategies which can be employed to increase the *effectiveness* and *efficiency* of the instruction (from a learner's perspective, of course!)



Personalizing and individualizing strategies can be applied to both curriculum decisions (which are concerned with *what* is presented) and instructional decisions (which are concerned with *how* this material is presented).

As a general proposition, personalizing strategies are more applicable to macro-logistics, and individualizing strategies are more applicable to micro-logistics. Macro-logistic strategies, which deal with the manipulation of Chunques, are primarily concerned with the selection and sequencing of these basic pieces of instruction. The decisions which must be made are more concerned with what Chunques to select, and the order of presentation. A significant benefit of these decisions is the creation of appealing learning experiences. Micro-logistic strategies, on the other hand, are primarily concerned with instructional decisions which provide the learner with the necessary transactions within a Chunque. These strategies are more significant in creating effective and efficient learning experiences. The discussion here is limited to macro-logistics and the progression of a student through pre-existing Chunques.

5.4 PATHS

I call the set of Chunques that is selected and sequenced to create a customized course a *path*. An instructional path is a predefined course through a set of learning experiences that is tailored to match the *anticipated* needs of specified learners in much the same way that the paths through Banff park are designed for the normal tourist. Therefore, a path is an *anticipatory* best guess at prescribing an optimal sequence of learning experiences for a student. Macro-logistic strategies prescribe multiple paths that can be either (or both) *personalized* and *individualized* to provide optimal benefits in efficiency, effectiveness, and appeal to those learners.

The design of a path must reflect the goals and needs of the learners, because within the broad curricular goals, the customized paths for each learner will have different and specific requirements. These requirements will vary depending upon the entry level knowledge and skills possessed by the learners, on the sophistication of the learning strategies they possess, and on the particular goal of each learner within the broad curricular goals, among other things.

The design of a path must also relate back to the kinds of goals in the curriculum, as described by the Three Souls proposition. The path definition must relate to the goals of the curriculum because the collection of Chunques which comprise a path must be different if the curricular goal lies primarily in the Education-to-Be domain, the Sagacity-to-Know domain, or in the Training-to-Do domain. Different goals require a different mix of learning experiences.

The degree to which a program can be customized to suit each learner is a function of the sophistication of the learning system, whether it be human or machine based. For instance, in many large lecture based classes, there is little attempt to customize the courses to meet the needs of individual learners, while in a number of recent videodisc based courses, customizing is employed to the extent that it is possible that no two students will receive the same program.[3] It is self evident that the more sophisticated the learning system is, the more complex the path strategies can be. However, the Chunque Theory suggests that even with no technical enhancement, a successful learning system can be created in a typical classroom.

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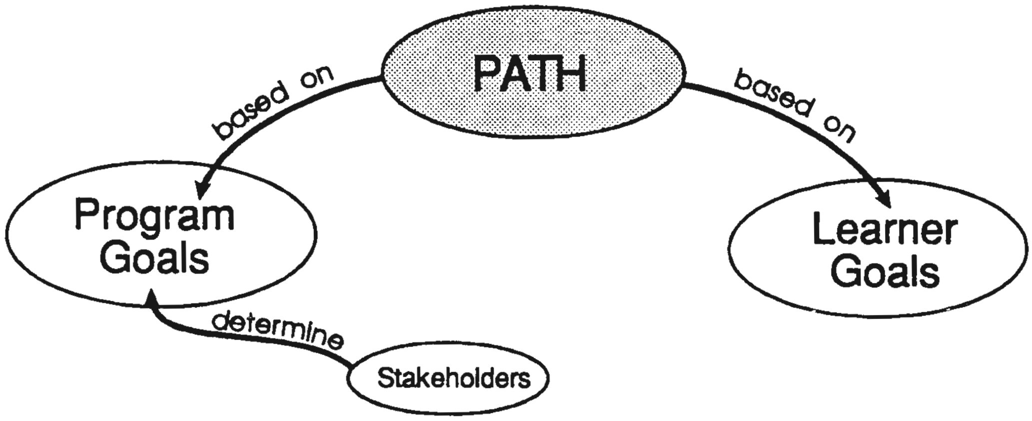
[3] This is based on conversations with DeBloois during 1984 and 1985. He gave an example of a videodisc training program for missle carriers that had twenty three levels of remediation.

5.5 PATHS, PROGRAM GOALS, AND LEARNER GOALS

The choice of a kind of path to develop is dependent upon two concerns: the goals of the program, as described in Part Three, Representing a Curriculum, and the goals of the learner. Even through the Chunque Theory continually stresses that the interests of the learner must be the primary concern in the design of a learning system, this position must be modified when considering whether program goals or learner goals should predominate.

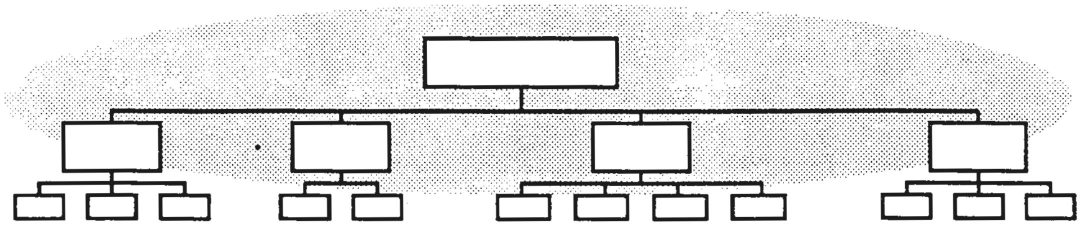


In balancing the interests of the program and the learner, one can take the position that the underlying purpose for the existence of any program is defined in program goals established by external stakeholders in the value laden curriculum. Within the confines of the value laden curriculum, the path prescribed for any learner must be customized to incorporate the particular goals of that learner. This consideration is most often of concern in public education rather than in industrial or commercial settings. In post secondary education, primarily when dealing with adult learners, there is often pressure from the learners to redefine programs to meet their concerns rather that program goals.

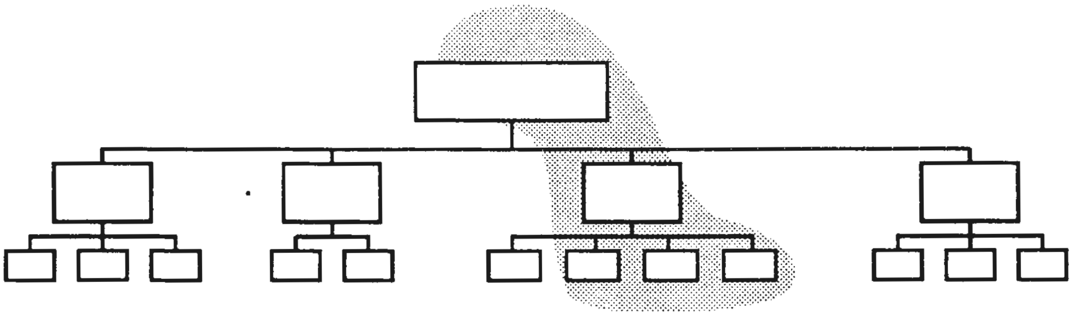
Although this is primarily outside of the scope of instructional logistics, being of a more political or philosophical nature, it is often the case that these concerns to some extent determine the course of events. In the discussions that follow, the stance is that paths should be designed to reflect learner goals within but not be at variance with value laden program goals.

5.6 KINDS OF PATHS

Let us turn to the general kinds of paths that can be developed. The three most general kinds of paths are broad paths, deep paths, and spiraling paths.[4] A broad path provides a horizontal sweep across the most general and significant ideas within a domain to provide meaningful understandings of a wide range of notions and their interrelationships. It provides knowledge *about* a domain, and should provide a unified but shallow model, lacking in specific and detailed knowledge. It falls within the realm of Sagacity-to-Know.



A narrow but deep path structure provides in-depth and detailed knowledge of a restricted array of selected ideas from a domain. The primary application of vertically structured paths is in situations where the learner is required to have expert competencies to accomplish specific tasks within a restricted field, but is not required to have a broad comprehension or a global perspective. The most common application of narrow and deep paths is within Training-to-Do.



The spiral path is an application of Bruner's[5] notion of circling back through the same ideas in greater depth during repeated passages through the same domain. Spiral paths are most appropriate in long duration or comprehensive paths, where there is sufficient time to develop a truly all encompassing understanding, as in Education-to-Be. The learner who completes a spiral path through a domain might be more likely to develop intricate and progressively more detailed understanding of the domain, elaborating on the initial broad but general passes on each successive cycle.

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4 This is taken from telephone conversations with Reigeluth in the spring of 1989.

5 Bruner, J. S. (1966). *Toward a theory of instruction.* New York: Norton.

5.7 GENERAL PATH STRATEGIES

These three basic path structures define the general structure of a path, but do not address the sequence of the Chunques within whatever structure is developed. The Chunque sequence can follow any of several (or possibly infinite) sequencing strategies. A couple of common examples are briefly described here, and some others from the PASSPORT program in the following sections.

A chronological path sequence lays out the Chunques in a time sequence, as is common in historical or biographical works. However, use of this common sequence should be tempered with a consideration of whether it aids in the development of a meaningful understanding for the learner. I suspect that the internalized structure of the mental model developed by many people does not match a chronological sequence, but rather is based on other more meaningful relationships between the notions in the domain.

Closely related to a chronological sequence is a procedural sequence, where steps in a procedure must be performed in a particular order. However, because the steps must be *performed* in a particular order does not imply that they must be *learned* in the same order.[6] None the less, the competency that is finally developed must recognize the order of performance. If, for instructional reasons, the steps are learned out of sequence, additional instruction might be needed throughout the learning experiences to insure that the steps are internalized into an appropriate model.

There are two aspects to creating paths, selection of appropriate Chunques and sequencing of the Chunques. Selecting which Chunques from the curriculum map to include in any particular path is primarily a curriculum decision, concerned with determining *what to teach*. However, in some circumstances, Chunque selection can become an instructional decision, if the reason for including particular Chunques is based on the need for a student to master the capabilities in the Chunque in order to successfully tackle another Chunque. The most obvious situation where this would occur would be in a prerequisite sequence of Chunques, where mastery of preceding Chunques would be essential in order to understand the new material. Another situation would be in providing upgrading or remediation, where particular Chunques could be included in the path to provide further instruction in areas where the students had not achieved mastery. The paths in the PASSPORT adult basic education program that are described in the next section represent different kinds of path strategies to address different kinds of goals. They also illustrate path strategies that address in a general way how to move through the Chunques. They represent whole and partial paths covering most or little of the range of available Chunques in the PASSPORT curriculum map. They also illustrate narrow and deep paths, or broad and shallow paths. They do not include spiraling paths patterned after Bruner's spiral curriculum.[7]

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[6] Bloom, *Human Characteristics,* (p. 27). Paul Merrill discusses this also in Merrill, P. F. (1987). Job and task analysis. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 141-173). Hillsdale, NJ: Lawrence Erlbaum Associates.

[7] Bruner, *A theory of instruction.* The notion of a spiral curriculum, when applied to path design, is a combination of selection and sequencing strategies, and also depends to a large extent on the structure of the subject matter domain as represented by the curriculum map. This is addressed in more detail in Part Seven and again in Part Ten, Mnets.

5.8 SOME EXAMPLES OF PATHS FROM THE PASSPORT SYSTEM

An instructional path is a predefined course through a set of Chunques that is tailored to match the needs of particular kind of learner. In the PASSPORT learning system, a number of predefined paths were available, some of which provided certification of mastery, others which did not. An overview of typical path structures is given below:

1. A Total Course Path. The student would be registered in a comprehensive course of studies, and would be required to demonstrate mastery in all (or a large cluster) of the Chunques. This path is analogous to reading an entire book, and would lead to certification.

2. A Particular Knowledge Path. The student would be seeking specific knowledge or skills. This is analogous to an "Index" mode of investigating a book. The student would know specifically what was wanted, and would register for specific Chunques. This path would lead to certification in those Chunques.[8]

3. A Browse Path. The student would want to explore the curriculum map to see what content was available and interesting. This would be analogous to a "Table of Contents" mode of investigating a book. The student would not know specifically what was wanted, but would choose based on ideas presented by the system. This path would lead to certification in the Chunques completed.[9]

4. A Skim Path. This path is analogous to reading the summaries at the end of book chapters, or the first paragraphs of magazine articles, to get the gist of what was discussed. The student would want to gain broad understandings of the scope and significance of the Skills Profile. The system would prescribe a broad brush stroke across the range of Chunques, covering only the top level (most simplified) elaborations of the ideas. The student could choose the sequence of presentation, but not the scope. This path would not lead to certification.

5. A Procedural Path. The student would want to gain limited procedural skills for a specific crucial task. The content would be specific with contextual or broad understandings eliminated. This path would not lead to certification in the usual sense, but could lead to certification of very specific skills on an individual basis. This path would be analogous to reading a specific chapter in a text book.

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[8] Paths of this sort are reactive, in that they provide content in response to a learner's preconceived notions of his needs.

[9] Paths of this sort are proactive, in that they provide the learner with guidance in selecting content areas that were previously unknown to the learner.

5.9 MAKING A PATH ON THE FLY: A ROUTE

The paths in the Banff park were described as anticipatory paths through the forest, designed in anticipation of the desires and needs of the tourists who would use them. However, I suspect that very few tourists actually stay on these paths all the way from the highway to the lake. Many of us take short excursions to explore the terrain off to one side or the other, some of us strike out into unknown territory for a while before returning to the path. Although our goal is probably still to reach the lake, we do not follow the path laid out by the park people. We design our own route on the fly, depending on the whim of the moment or our basic underlying interests. While the formal path is created in anticipation of our needs, our course is adapted as we go to create the actual route we devise to reach our goal. The path is a best-guess solution to anticipated needs, the final route is the result of adapting to the ongoing situation.

The destination is predetermined: to get to the lake. The path is designed as an optimal way to get from the beginning of the trip to the end. But along the way, you may stray off of the path for any number of reasons ... you may see a short cut, or your interests may lead you in another direction, or you may just get lost.

In instructional logistics, the course set out for a particular learner is usually a path, designed in anticipation of the needs and desires of the learner. But, just as you may digress from the path to the lake, a learner may wish to (or need to) digress from the instructional path, either due to the interest of the moment or because of instructional needs.

The route taken should be the optimal progression for that particular learner, determined as the learner progresses through the program, and taking into account the unanticipated happenstance of the actual learning experience.[10]

The distinction between a path and a route is that a path is a predetermined best guess, while a route is an objectively based interactive and on-going determination of appropriate learner progression. Path strategies are more sophisticated than traditional instructional design strategies, as they address the need for a multitude of paths tailored to the needs of individual learners. This is another example of the "teach each, not teach all" principle. Routing strategies represent a further sophistication, as they address the need to modify the selected path based on an ongoing assessment of learner needs.

PATH	ROUTE
Anticipatory	Adaptive
Based on Assumptions	Based on Data

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[10] See Tennyson, R. D., & Christensen, D. L. (1988). MAIS: An intelligent learning system. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 247-274). Hillsdale, NJ: Lawrence Erlbaum Associates.

5.10 ROUTING STRATEGIES FOR MACRO-LOGISTICS

Instructional routing strategies are macro-logistic methods used to construct paths in real time, based on an analysis of the student's accomplishments, needs, and desires at that particular time. Routing strategies are in one way counselling methods related to goals, and in another way instructional strategies in that they are based on diagnosis of student misconceptions.[11] In the first case, a student would approach a program with the intention of accomplishing certain value-laden goals. In this instance, the routing strategy would prescribe an anticipatory path that would correspond to the wishes of the student.

In the second instance, appropriate routing strategies would diagnose the entry level skills of the learner and prescribe a suitable starting point in a path, and later evaluate student achievement and prescribe either a "fast track" route for an accomplished learner or a more detailed route for a less accomplished learner. The result, in any case, is to prescribe an initial best guess path and then modify it on the fly to suit the individual and the situation. Personalized instruction deals with the student choice issues connected to this; individualized instruction deals with student achievement and how to provide optimal learning experiences to maximize achievement.

It would seem to me that creating anticipatory paths for particular learners is a vast improvement on teacher based and teacher paced instruction, but that adaptive routing strategies hold the promise of creating optimal sets of learning experiences for each student. If we can find ways to use the power of computer managed learning systems to accomplish this task, the benefits to our students could be significant. Alas, it does not appear that is the case with currently available systems, but that is a problem for another book and another day.

	ANTICIPATORY	**ADAPTIVE**
MOTIVATIONAL	A Personalized Path	A Personalized Route
INSTRUCTIONAL	An Individualized Path	An Individualized Route

An instructional route is a customized path that is created interactively during the progression of the learner through a set of learning experiences. In order to create a route, it is necessary to identify the characteristics and interrelationships of the curriculum required to create a path, and in addition, to develop a learning system that permits an ongoing adaptation of the path to meet the immediate needs of the learner. Informative evaluation strategies and adaptive sequencing strategies are used to create an optimal route.

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11 Gropper, G. L. (1983a). A behavioral approach to instructional prescription. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 101-161). Hillsdale, NJ: Lawrence Erlbaum Associates.

5.11 PATHING SCHEMES FROM ANTIQUITY

Prior to the advent of computers in education, the administrative and practical problems associated with keeping track of the course of action of a number of students progressing independently through a program in most cases mitigated against the use of customized programs. In the area of Industrial Arts, much work was done on methods of progression through shops or laboratories which did not have a sufficient quantity of equipment to permit all students to learn the same things at the same time. Because of this, some sort of progression scheme was seen as a necessary evil. These are three examples:

The most common progression scheme was *group rotation*, where students were divided into a number of small groups, determined by the number of work stations available for each area of content. The groups would then rotate in a time-based, lock step fashion through the various work stations. There was not much customizing under this scheme.

Individual rotation provided for the progression of each individual student through a number of work stations. This was usually used when only a single workstation was available for each item of content. Progression was still time based, with all students rotating to the next workstation at the same time, but there was often some flexibility for the student to chose among the stations.

Individual progression schemes allowed each student to progress to another workstation upon completion of an assignment. This method was rarely used, due to the administrative overhead involved in keeping track of each student, and in providing independent instruction to each student when required.

The INSCITE program extended these equipment-centered progression schemes to become learner-centered progression, where the student could personalize the program to meet individual choices of content. This was possible because, in the INSCITE program, the particular content of any Chunque was an example (an instance) of a more general principle (the generalization). The INSCITE program goals were primarily in the Sagacity-to-Know domain, where broad understandings were deemed more important than specific knowledge or skills. In Sagacity-to-Know programs, the primary focus is on the understanding of principles.[12]

The instructional modality[13] used for the particular content (instances) was expository, while the modality for the generalities (principles) was directed discovery.[14]

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12 Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates..

13 Instructional modality is a term used at the Canadian Centre for Learning Systems to describe an instructional mode, such as directed discovery, simulation, or (one of my favorites), bland.

14 Joyce and Weil discuss the need for carefully planned lessons when a directed discovery mode is used, in Joyce, B., & Weil, M. (1980). *Models of teaching* (2nd ed.). Englewood Cliffs, NJ: Educational Technology Publications.

5.12 HOME BASE

I mentioned in the example of a route through the forest that you might just get lost. One not uncommon problem with individual progression and other customizing schemes is that students sometimes just get lost. One strategy to help prevent this is to create a home base for the student.

The *home base* is where the student receives guidance in developing a customized path through the instruction. The home base is typically comprised of a number of synthesizing Chunques which contain the initial orienting instruction, an assessment center which certifies competence, an array of remediation or upgrading Chunques and a road map of some sort with a "signposting"[15] scheme to let the students know where they are at in the program.

The home base, whether it be a computer terminal for computer managed learning implementations, a classroom in a traditional setting, or an outreach site with an instruction manual and a "facilitator" who is not a content expert, is the organizational center where the student sets a course through the curriculum. At the completion of any Chunque, the student returns to this home base to set out on a new direction.

The home base is the heart of a Chunque-based learning system. The home base provides a personalized route[16] through the curriculum for each student. It is the organizational center where the student, usually in consultation with a mentor, sets a course through the curriculum. Typically, the home base would direct a student along a path at the Chunque level. All instructional logistics tasks above the Chunque level[17] will be handled by the home base; all logistics tasks within Chunques[18] will be handled by the Chunque itself.

The home base would consist of all of the Chunques above the primary, lowest level ones. All of these higher level, synthesizing Chunques would focus primarily on linking knowledge and on introductory lessons to provide an overriding framework within which the primary level Chunques reside. Thus, if one were to follow a skim path, one might not get to the level of the primary Chunques. If one followed a procedural path, one might not get many of the higher level synthesizing Chunques, and would lack meaningful contexts within which to place the procedural knowledge.

This becomes a complex problem, deciding what to leave out. Also, it gets tricky to determine where to place certain ideas. For example, the most general notion in a primary-level Chunque might also be the most specific notion in a synthesizing Chunque. Where should these notions go? We will deal with this later.

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15 This is from the work of Michael DeBloois on multiple paths and knowing where you are in a path through signposting, from discussions at Utah State University in 1984 and 1985.

16 A personalized route for each student does not imply independent instruction. Rather, each student would be enrolled in modules based on an assessment of student desires. The delivery strategy used to present these modules could range from classroom lectures to telephone conference calls.

17 These are macro-logistics tasks.

18 These are micro-logistics tasks.

5.13 PATHS AND CERTIFICATION

Some of the paths described earlier will lead to certification in a program of studies while others will not. Certification in a program is typically granted for completion of a number of core courses and a selection of options which combine to total a requisite number of course credits. A problem which often arises concerns the learner who wishes to study some parts of a program and is not interested in others. Usually little formal recognition beyond a transcript of marks is granted to a learner who chooses to complete only part of a predefined program. Often, part time and evening learners complete studies under the umbrella of continuing education which are similar or identical to credit courses leading to certification, but are not granted either formal credit or program certification.

The fundamental goal of instructional logistics is to create programs which foster customized programs for particular learners. Obviously, this goal is often at variance with traditional institutional certification policies. To incorporate customized learning systems into such a culture requires careful consideration of certification policies. This was a basic concern in the development of the PASSPORT system. The title PASSPORT was chosen, in fact, because of this concern.

The solution was to develop a certification policy that provided formal recognition and certification for each Chunque in the package rather than for the package as a whole. This was crucial, as no students were expected to compete all of the Chunques comprising the package.

The analogy used to illustrate the certification scheme was based on the booklets used in Sunday schools discussed earlier. In the Sunday School example, recognition of each accomplishment was given, and a record of achievement was illustrated by the number of gold stars in each student's booklet. Upon gaining all of the stars, the certificate was complete. These gold stars were granted for units of content corresponding to the Chunques.

5.14 CERTIFICATION IN PASSPORT

The passport idea was transformed into a "Passport to Living" for the adult basic education students in the PASSPORT program. The passport contained sections for each of the major content areas (called bands) in the curriculum map. Within each section were areas for each unit, which corresponded to Chunques or modules, depending on the nature of the ideas in the map. When the learners achieved mastery in any Chunque, certification in that particular Chunque would be granted, and recorded in their passport.

The layout of the passport provided a graphical representation of the curriculum map, designed to foster the acquisition of an appropriate mental model for the learner, and provide a sort of advance organizer.[19]

There were a number of different passports with predefined paths leading to certification in recognized programs which the PASSPORT learning system was replacing. Each of these were to be comprised of Chunques selected from the total array by advisory committees and institutional departments, and were seen as comparable to existing courses or programs. In other instances, customized passports could be defined for individual learners as a result of counselling or placement tests and learner requests. These were to be printed and provided to learners upon entry to the program. In still other cases, passports were to be provided that only indicated the initial Chunques in the anticipated program, as the learners did not know which Chunques they wanted to address. In this case a customized route developed as the student gained an understanding of the nature of adult basic education goals and opportunities.

As can be imagined, if this was implemented over several institutions and many outreach and distance education sites, certification problems could have developed into a nightmare. A partial solution was to develop guidelines for the kinds of paths that would lead to certification for clusters of Chunques and those that would not. In either case, certification was to be granted for each Chunque, regardless of the possibility of certification as a program for any cluster. In this manner, any learner would gain "gold stars" for mastery of each Chunque.

In the description of some of the paths in the PASSPORT learning system presented earlier, an indication was given of which paths lead to program certification and which do not. In general, shallow paths and scattered paths are not eligible for program certification, while deep paths usually are. This was more a result of institutional culture than any plausible learning system theory.

The more formal or certifiable the program, the more path constraints there are, but only for personalizing. Path constraints on individualizing are more technical.

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[19] Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart, Winston.

5.15 PROGRAM LEVEL CERTIFICATION

In an ideal learning system world, I suppose granting certification on a per-Chunque basis with analysis of what that meant left to the interpretation of prospective employers or other external stakeholders would be the desired goal. However, that is unrealistic, as most stakeholders do not have the knowledge base to understand what certification means. They want and need a program related certificate.

The Chunque Theory prescription for this is to grant certification for each Chunque that is mastered, and program certification for a predetermined cluster of Chunques comprised of all essential Chunques and an array of optional and enrichments Chunques. After identification of the Chunques considered to be essential, the widest possible choice of additional Chunques should be allowed to round out a program.

I especially like the passport metaphor with a graphic representation of the relationships between the various Chunques in either a predetermined path or a developing route, as this provides the basis for a corresponding representation of the subject matter for the learner, the institution, and the reader of the passport. Alas, the likelihood of this scheme gaining acceptance in most institutions would appear remote.

In the design of the PASSPORT learning system, we were fortunate not to suffer these constraints, primarily because the program was envisioned primarily as a distance learning system, somewhat remote from entrenched institutional cultures. When the program was delivered within an institutional setting, the institution was required to follow the logistics strategies developed for the distance delivery program, rather than establishing a traditional institutional scheme.

It is constructive to recall that the program was scrapped by the institutions, however. There must be a lesson there somewhere.

5.16 SYNTHESIS

A learning system designer can construct four different kinds of paths: anticipatory individualized or personalized paths, and adaptive individualized or personalized routes. In practice, it would seem that prescribing a combination of these different kinds of paths would result in a learning system that would provide the optimal balance between efficiency, effectiveness and appeal for a given learner. The point of all this is that these different customizing schemes require different strategies depending on the particular situation. In order to accomplish this, the curriculum must be represented in a way that organizes the Chunques to provide an appropriate structure for creating customized paths.

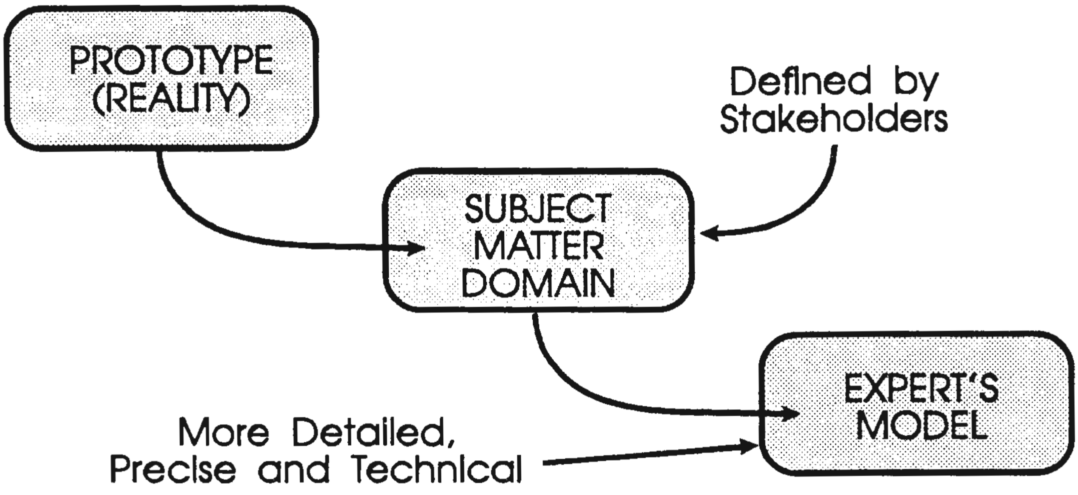
It would seem that, if a complex knowledge domain were represented by a large, multi-level hierarchy ranging from very simple and general ideas at the top down to very specific and detailed ideas at the bottom, a given course would take a slice out of this hierarchy at a level that was deemed appropriate for the goals of the particular course. This slice, when developed through the DACUM process, usually ends up being about three levels deep. I suspect that this is about right for a learning system, with the most general ideas comprising the upper-level synthesizing Chunques, the heart of the system based on the primary-level Chunques, and the transactions within the primary Chunques providing the "technical" ideas which foster mastery of the capabilities defined in the primary Chunques.

The expert's models described in Part Three do not seem to be optimal for this task. They might be too complex, and represent too many levels to deal with in one course or program. There is a difference between representing a domain in a very deep hierarchy and representing the notions within a learning system to deal with a particular set of curricular goals. What is needed is a representation that is more suitable to the needs of educators as they develop a learning system. This educators' model of the domain is called a *curriculum map*. It will be the topic of the next chapter.

PART SIX: COURSE BUILDING

6.1 REPRESENTING A SUBJECT MATTER DOMAIN

Back in Part Three a distinction was made between the *subject matter domain* that would be described by the stakeholders in an education program and the more detailed, precise, and technical *experts' model* that would be formulated by subject matter experts or curriculum committees that were intimately familiar with the domain. This diagram illustrates some of the characteristics of each of these models and their relationships to reality, which I will call the *prototype*.



An expert's model of a curriculum is constrained in scope by the subject matter domain defined by the stakeholders. It is an expert's representation of the domain specified by the stakeholders, which is a value-laden determination.

Both of these models of a domain are intended to represent the entire domain. They are supposed to be all-inclusive models of the subject matter or content that should be included in the program or course.

6.2 PROBLEMS WITH EXPERTS' MODELS

One of the primary principles of needs assessment is to determine the gaps between what is and what should be.[1] Expressed in another way, the purpose of needs assessment is to determine what it is that students must learn to get from where they are now to where they are intended to be at the end of a program. Subject matter domains and experts' models do not recognize this principle: they are specifications of the capabilities of successful graduates at the end of the program, and thus include everything that should be known at the completion of study.[2] This can cause some considerable problems if these domain representations are used to create a course without regard to what the incoming students already know. Unfortunately, this is sometimes the case both in public schooling and in training courses. This will be discussed later in this chapter under TOWTDAK strategies.

Another shortcoming of the domain representation of experts is that they are structured from the perspective of an experienced practitioner or expert rather than from the perspective of a novice learner. Often, this expert's representation is used as a framework for developing courses, and the courses reflect the structure of this representation. For example, the DACUM competency profiles introduced in Part Three are intended to be used to develop courses. The courses quite often consist of units mirroring the boxes in each band of the profile, with the student learning the subject matter in the first box in detail, then moving to the next, and so on. When one band is complete, the student begins at the first box in the second band and so on. This sounds suspiciously like course organization that is based on the topics in a text book, doesn't it?

I maintain that this is an inappropriate way to develop courses. It promotes fragmented knowledge and does not provide an optimal scaffold the student can use to build an appropriate mental model. This is because it is based on the complex and intricate subtleties of an expert's view of the domain rather than a teachable beginner's representation.[3] This chapter describes what I think might be a better way.

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1 See Rossett, A. (1987). *Training needs assessment.* Englewood Cliffs, NJ: Educational Technology Publications.

2 I am going to use the general term *course* to describe educational programs in general, including individual courses, programs, and other learning systems that consist of more than one chunque of content.

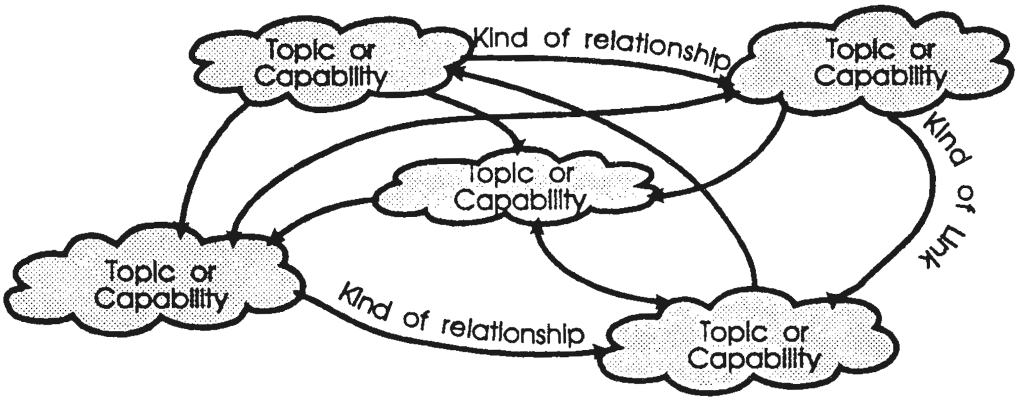
3 The difference between a knowledge representation and an instructional representation was introduced earlier in Section 3.18.

6.3 INSTRUCTIONAL LOGISTICS AND COURSE DESIGN

The Chunque Theory proposes transforming the experts' model into a *curriculum map*. Let's assume that the experts' model is structured like the DACUM chart illustrated earlier. The method proposed here will work equally well regardless of the nature of the experts' model, but a DACUM chart provides a suitable example. Faculty are asked to look at the competencies or capabilities represented by each box in the DACUM chart (or other domain hierarchy) and to select a few boxes that embody the *essence* of the domain. In making a choice, the faculty are asked to consider this from a student's perspective: to select those which are optimal in representing the nub of the domain to a naive learner.[4]

We point out the difference between the kinds of things they would tell a colleague, another expert, a newspaper reporter, or a prospective student. We ask the faculty to consider what they would tell a prospective student if they only had a few minutes, and they really wanted the student to enroll in their course or program. This process aids in identifying a number of aspects of the domain that provide a simplified model for a novice.

These topics from the DACUM chart are stuck up on a whiteboard on pieces of cardstock in no particular arrangement. We actually use pieces that are diecut into the shape of clouds, which seems to dispel any notions that they form any sort of hierarchy or rigid structure. Then the faculty are asked to tell us about a few cards that are related in the most significant way. These cards are connected with lines, and the nature of the relationship between the cards is written along the lines, with arrows showing the directionality of the relationships, if any. This process is continued until the clouds are linked together by whatever relationships are apparent to the faculty. The result is a chart that looks somewhat like this:



The most significant chunques are arranged into a relational network based on the characteristics of the links relating the chunques. It is essential that the links be analyzed with rigor equal to the chunques.

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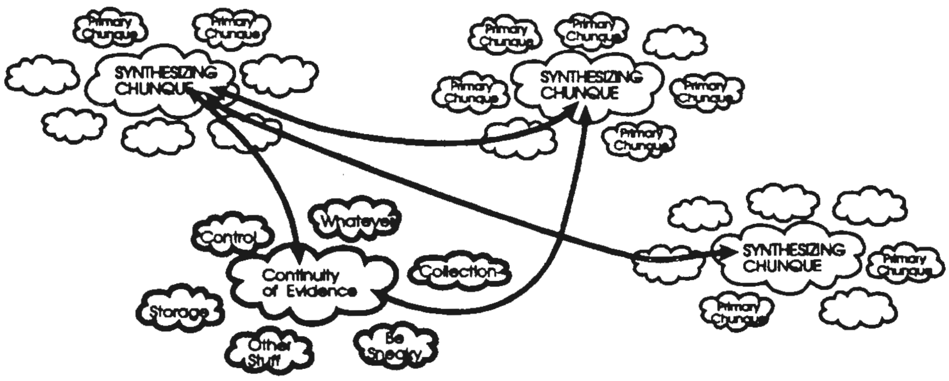
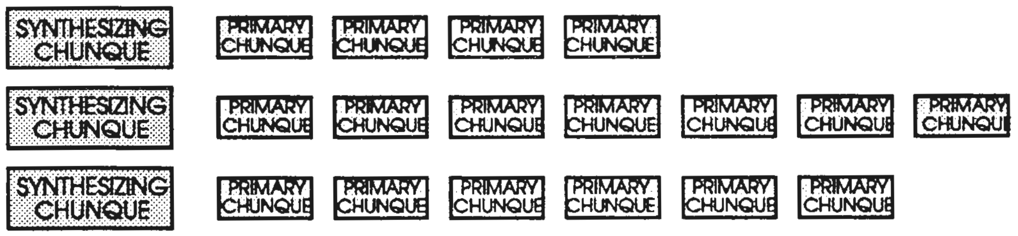
4 This is much like the *epitomes* suggested in the Merrill/Reigeluth Elaboration Theory. See Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates.

6.4 CLUSTERS AND CLOUDS

To elaborate on the initial network for a domain, faculty are asked to select additional boxes from those remaining on the DACUM chart, starting with the most significant, and cluster them around the appropriate cloud in the initial network. This process continues until all of the boxes are transformed into clusters of clouds and relationships. The important point is that, at each level, the raison d'etre for the formation of particular clusters is the significance of the relationships among the clouds *from a student perspective* rather than the typical conceptual hierarchical structure of the domain expert. The resulting network looks something like this:



Each large central cloud represents a set of capabilities (that would become a synthesizing Chunque), connected to a number of smaller clouds representing the primary Chunques. Thus an educator's model of the domain develops from this initial seed through clusters of related notions. This perspective emphasizes the links as much as the nodes, and avoids the fragmentation that hierarchical structures produce. It is a transformation of the complex model of the expert into a more simple model appropriate for a beginning learner. I call this a *curriculum map*. They are sometimes arranged like this:



This looks suspiciously like a DACUM profile, but it isn't. This diagram represents clusters of notions based on assumptions about the significance to students of the relationships between them. But this form of diagram once again looses information about the links while emphasizing the nodes. The relational network provides a much more accurate and rich representation.

6.5 FROM CLUSTERS TO LEARNING EXPERIENCES

To transform a relational network into a set of learning experiences, each major cloud forms the nucleus of a course and each of the clusters of clouds at the next level forms the units. We perform this operation with absolutely no concern for the practicalities of the situation (the educational setting), basing the development solely on what appears to be an optimal network of ideas for the learners. Administrative constraints come into the picture later.

This process results in a curriculum map that illustrates a number of possible paths through the clouds, always based on the significance of the connecting links between the clouds. The problem is, it does not reveal which is the optimal path for any given student at any particular moment. Ah ... the rub!

How we determine which relationships are more significant to students is an open question, but I think it is fair to assume that significance to students might be substantially different from significance to domain experts or faculty. The basis for determining guidelines for this can be derived from Norman, Minsky, and Denenberg,[5] and will be discussed more fully in Part Ten: MNETS.

Briefly, the assumption is that as the student's mental model of the domain evolves, the initial array of fragmented situational representations will coalesce into more generally applicable and robust representations that pertain to a wider domain. Instances become generalities.

Let's reflect on what this has created.

It is a web of relationships that are seen by our faculty experts as the essence of the domain as defined by the stakeholders. We point out that the purpose of this exercise is to create a network that is the best we can find from the perspective of significance to a novice learner. This usually results in a modification of the clouds and their relationships; a tune-up, if you will. An interesting point here is that the faculty become, in addition to subject matter experts, advocates for a representation of the domain for students. Their dual expertise as domain experts and educational experts is indispensable in transforming the hierarchical structure of the expert's model into a network that represents both the ideas and their interrelationships to the student in a simplified vision of the most critical aspects of understanding.

This is the nub of the instructional logistics mindframe.

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5 This is drawn from three works. See Denenberg, S. A. (1988). Semantic network design for courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 307-326). Hillsdale, NJ: Lawrence Erlbaum Associates; Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster; and Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books.

6.6 CUSTOMIZING STRATEGIES

The curriculum continuum suggests that goals and objectives can be arranged on a continuum from the most value-laden to the most technical. The Three Souls proposition suggests that a curriculum can be analyzed and the goals categorized into three classes that can help to clarify what the instruction should be like. But how can this curriculum be represented? Typically, some sort of graphical representation is created, often called a *scope and sequence* chart.

In Part Five a description of customizing a learning system by creating an optimal path for each learner was presented. In this section, a number of instructional strategies for prescribing which Chunques from a curriculum map to include in the creation of an optimal path for each combination of learner, idea, and situation will be discussed. The goal is to piece together a meaningful path by selecting and sequencing Chunques based on current instructional design theory. The problems facing a learning system designer are, first, to determine which Chunques are needed to create an optimal program, second, to determine the possible sequences for those Chunques, and third, to decide which combination of learner control and system control will provide the optimal sequence for a given situation. This will aid in creating a path which is optimal for *this* learner tackling *these* ideas in *this* situation.[6]

Earlier, two kinds of customizing strategies were defined depending on the desired outcomes, first whether the customizing was anticipatory or adaptive, and second, whether the customizing was for instructional or motivational reasons A matrix defining personalized or individualized paths and routes was used to illustrate the four possible classes of customizing strategies.

	ANTICIPATORY	ADAPTIVE
MOTIVATIONAL	A Personalized Path	A Personalized Route
INSTRUCTIONAL	An Individualized Path	An Individualized Route

You will recall that the difference between a path and a route is that a path is a predetermined best guess at an appropriate sequence of Chunques, while a route is an adaptive path created on the fly, based on a continuing assessment of the interaction between the learner and the system. Most of the macro-logistic strategies presented here apply equally to paths and routes. It matters not whether a path is predetermined or a route is created in real time; in either case the strategy should be relatively transparent to the learner.

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6 This notion of prescribing strategies for particular instructional instances is drawn from Gagne, R. M. (1987). Introduction. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 1-10). Hillsdale, NJ: Lawrence Erlbaum Associates.

6.7 SELECTING CHUNQUES TO INCLUDE IN A PATH

In Part Three, Representing A Curriculum, a number of strategies for determining the nature of the ideas to include in a curriculum were presented. These strategies fell into two broad categories, those concerned with the value-laden curriculum and others concerned with the technical curriculum. We looked at creating a curriculum map from a DACUM profile by clustering the ideas. The curriculum map that is derived from utilizing these strategies specifies *all* of the ideas that comprise the curriculum domain. At the primary Chunque level, these ideas can be classified either as essential, the ones that every learner must master, or as enrichment, the ones that would move the learner beyond a minimum acceptable level to a more desirable and more inclusive level.[7]

Earlier, we explored the notion that efficiency, effectiveness, and appeal can be viewed from the perspective of the learner, the faculty, or the institution. A curriculum map does not consider the perspective of the learner. Curriculum maps define the range of ideas to be included in a curriculum, and are independent of any particular learner. They are (or at least should be) viewed from the perspective of external stakeholders such as employers, lay boards, the public, and so forth. However, the basic tenet of learning system theory is that everything should be considered from the perspective of the learner. Curriculum maps are not: they represent the capabilities that would be held by the superlative graduate.

The whole intent of instructional logistics is to manage the progress of a learner through a curriculum. The point of path strategies is to select and sequence a customized array of Chunques for the learner drawn from the curriculum map, and including only those which are required by that learner to master the capabilities in the curriculum map. Therefore, instructional logistics must address not only the issue of which Chunques from the curriculum map to include, but also which to exclude in designing a path.

An underlying assumption here is that not every learner will require instruction in every Chunque in the curriculum map. There are several reasons why this might be so. A primary customizing strategy is based on this classification of Chunques into essential, optional, and enrichment categories. The path for any learner must include all of the *essential* Chunques and a range from the optional and enrichment Chunques. A curriculum map of the domain would include *all* of these Chunques, while the path for a particular learner could exclude some of them on the basis that mastery of certain skills or knowledge is not required for the particular learner.

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7 This notion of excellence beyond minimum mastery levels will be discussed in depth in Part Eight: Assessment and the Pursuit of Excellence.

6.8 CHUNQUE SELECTION CONCERNS

Typically, specializations within a curriculum domain are not recognized while the curriculum map is being developed and, I suspect, should probably be ignored by the learning system designer in any case, as the curriculum map should be as all inclusive as possible. It is much easier for a learner or the system to select a path from a too-inclusive set of Chunques than to recognize and include Chunques or ideas that are excluded from a too-restrictive curriculum map.

This strategy is a curricular selection strategy based on identifying sub sets of program goals, and is a common event. It is neither a personalizing strategy or an individualizing strategy, but a goal-driven strategy required by the realities of curriculum map development. In the PASSPORT project, the curriculum map identified approximately one thousand objectives that comprised the range of competencies identified as necessary to be certified as a "competent adult" in Alberta. However, it was never intended that every learner should be certified in every one of the one thousand competencies. A range of Chunques was selected for each learner based on what could be termed "customized priorities."

In a recent curriculum committee meeting for an accounting program, a group of prospective employers was reviewing course content, and all generally agreed on the competencies they required for beginning employees, but pointed out that some of the graduates would want to continue their studies towards obtaining an accounting credential. These students could challenge certain professional examinations if their program included some specific content. As a result, some students would be aided by including Chunques not identified as required by the prospective employers, but helpful in career advancement. The problem was that the curriculum committee recognized from past experience that many of the students would never attempt to obtain a professional designation, and those that would could not be identified in advance. The dilemma faced by the committee was whether to include the content in the program. Because the program was instructor centered rather than learner centered, all of the students had to take the same classes. Which ever way their decision went, the program was less efficient, effective, and appealing for some students than for others.

In a student centered learning system, this dilemma can be avoided as the learner or the system can create a personalized path. A personalizing path strategy is one based on student choice. By specifying which Chunques are essential, which are optional, and which are enrichment, a learner can create a personalized path comprised of all of the essential Chunques and a range of optional and enrichment Chunques. The need for an advisor to assist the learner in the selection of appropriate Chunques varies with the sophistication of the learner and the learner's familiarity with the domain.[8]

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[8] This advisor, in the PASSPORT system, would be in the first instance a series of video segments of human mentors located in the home base. We intended to use an interactive video "ghost in the machine" to fill this role. If the advice provided by this mechanized advisor was not sufficient, the student could access one-to-one tutoring with a real live person.

6.9 CLASSIFYING CHUNQUES

Thus far we have discussed three different customizing path strategies:

1. Classify Chunques as Essential, Optional, or Enrichment.

2. Select Chunques based on graduate specialization.

3. Select Chunques based on the learner's personal choice.

The first is based on an *external determination* of which Chunques are essential, optional, or enrichment, which constrains the possible choices of Chunques in any path. This is not really an Instructional Logistics strategy, as it is not learner centered, but domain centered, but it is central to the selection strategies.

The second is an *individualizing* path strategy that does not fit into the Chunque Theory, but certainly exists in the real world. It recognizes sub-sets of goals within a curriculum domain which determine the range of Chunques to be included in a path of a particular kind of graduate. This also is not strictly an instructional logistics strategy as it is goal centered, not learner centered. In the design of a learning system, it is preferable to consider a separate path for each kind of graduate from the beginning, and design a path to match that need. If there are a number of different specializations, they should all be treated as *separate entities*, and a path determined for each of them. Then, if it is discovered that there are a number of commonalities, these common portions of the path could be presented in a common course. This places the emphasis on the individual paths, and considers the commonality as an administrative convenience. The more typical strategy of providing a common course for all specializations and then tacking on or eliminating Chunques from this common program for certain specializations runs the risk of stressing the commonalities first and the specializations as an afterthought. Then, gradually, administrative convenience tends to increase the commonalities and decrease the customized learning experiences for each specialization.

The third strategy is a personalizing path strategy made possible by the first one. The student, hopefully with some advice, selects the range of Chunques that he or she is interested in studying. This range is constrained by two conditions; the essential/optional/enrichment status of the Chunques and the learner's perception of their value. This is also a motivational strategy which tailors the path to the desires of the learner within the bounds of the Chunque classifications.

6.10 TOWTDAK

A fourth path strategy is an individualizing strategy based on the TOWTDAK principle.[9] The TOWTDAK principle is an *efficiency* principle and an *appeal* principle which states "teach only what they don't already know". The TOWTDAK path strategy prescribes selecting for a path only those Chunques that contain ideas that the learners have not already mastered. This may seem so self evident that it appears pointless to bother considering, but the corollary principle, the TTWTAKAAA principle, is rampant in faculty-centered instructional systems. The TTWTAKAAA principle[10] states "teach them what they already know again and again." It is a non-individualizing, non-motivating principle subscribed to inadvertently by a substantial number of educators. The TTWTAKAAA strategy prescribes including the same Chunques repeatedly in different parts of a path.[11] A micro-logistics equivalent prescribes including the same transactions in a number of Chunques. By combining the two strategies, a truly impressive redundundancy[12] can be created.

The TOWTDAK strategy depends upon an accurate diagnosis of what the students already know. The conduct of this diagnosis presents the primary difficulty in implementing TOWTDAK prescriptions. There are two principle means of obtaining the required diagnostic information. The first is through *placement assessment* conducted when a learner enters the system. The second is *ongoing informative assessment* embedded within the instruction. Both depend on comparing the competencies possessed by the learner with the competencies required by the program goals at a particular time.

For an example of placement assessment, in many programs, new learners are given a bank of placement tests to determine at which point they should enter the program. This strategy compares current student capabilities with the entry level (prerequisite) competencies for a course (or Chunque), and slots the learner in at an appropriate point.

It must be emphasized that the TOWTDAK strategy addresses the *initial presentation* of ideas, not such things as review, remediation, synthesizing lessons, or organizing strategies such as a spiral curriculum. TOWTDAK is concerned with situations like the horror stories of students having to endure instruction in the same concepts repeatedly over the duration of a program not because there is anything new or because the students did not master it the first time, but because there is no integration across different courses or instructors.

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9 This notion is from Ken Carlisle's presentation at the Canadian Centre for Learning Systems symposium series in Calgary, Alberta. See also Carlisle, K. (1986). *Analyzing jobs and tasks.* Englewood Cliffs, NJ: Educational Technology Publications.

10 TTWTAKAAA is probably pronounced *TTWTAKAAA*, which rhymes with ka-ka.

11 This is not to be confused with the intentional micro-logistics strategy of prescribing practice activities, or the macro-logistics strategies of summarizing and synthesizing.

12 A scholar of little note, Dr Ashle, insists that this is the correct spelling of redundundant, even though it is somewhat redundant.

6.11 INFORMATIVE ASSESSMENT STRATEGIES

Continuing embedded informative assessment can be used to determine whether the student has mastered the ideas which have been presented, and to prescribe review, remediation, or tutoring based on the particular misconceptions of the learner at any given time. This micro-logistics strategy is an essential feature of within-Chunque design. The TOWTDAK strategy proposes that, incorporated within this assessment system is another set of diagnostic assessment measures that determine at the beginning of any Chunque whether the learner already has mastery of the ideas in the Chunque. This can be done automatically, under system control, or at the prerogative of the learner. Since Chunque specifications include a list of competencies for each Chunque as a part of the learner's instructional resources, the learner always has access to the required competencies prior to beginning any Chunque.

Chunque Theory progression strategies suggest that the learner be given the opportunity to challenge the assessment measures for any Chunque. The TOWTDAK strategy prescribes creating a path that excludes the instruction for any competencies already mastered by the learner. If the certification assessment measures for any given Chunque are valid, then determination of mastery must be based on student performance on these assessment measures. If there is reluctance by faculty to accept the principle of the learner being permitted to challenge these measures to prove mastery, it should be an indication that the assessment measures are faulty. There should be only two plausible alternatives: either the assessment measures are *valid*, and mastery can be certified by them, or, if certification cannot be granted based on the certification tests (assessment measures), they must *by definition* be inadequate, and must be changed.

If there is an insistence on a time-based component to granting certification, or an attendance requirement, a very close look at the relationship between the assessment criteria and the instructional program (or institutional culture) is warranted. Attendance requirements are usually a faulty solution to a different problem, such as a demand that certain ideas be mastered, but not including them in the assessment strategies. As a result, it is falsely assumed that insisting that learners be present when the ideas are presented will ensure that the ideas are learned. Attendance demands should always raise a red flag for the learning system designer.

6.12 PREVENTING DUPLICATION

Another component of the TOWTDAK principle is addressed by the partitioning strategies outlined in Part Four. If the curriculum is divided up into Chunques based on notions of worth, and the Chunques are clustered into an curriculum map, each curricular idea should appear in only one Chunque, and each Chunque should appear only once in the curriculum map. Then, when a path is created, each Chunque and idea should only appear once ... and the TTWTAKAAA problem is solved. TTWTAKAAA problems usually arise because either no formalized curriculum map exists, it was assembled incorrectly, or the program or courses are faculty centered, and each faculty member has created courses independently.[13]

To summarize the instructional logistics pathing strategies in this section, it comes down to a two step process. First, it must be determined what each individual student should know at the end of the program. The question is "describe for me the perfect graduate." The second step is to determine what the student needs to learn to match the description (fill the gap between what is and what should be). A path is then created from the curriculum map Chunques to provide those learning experiences. Simple.

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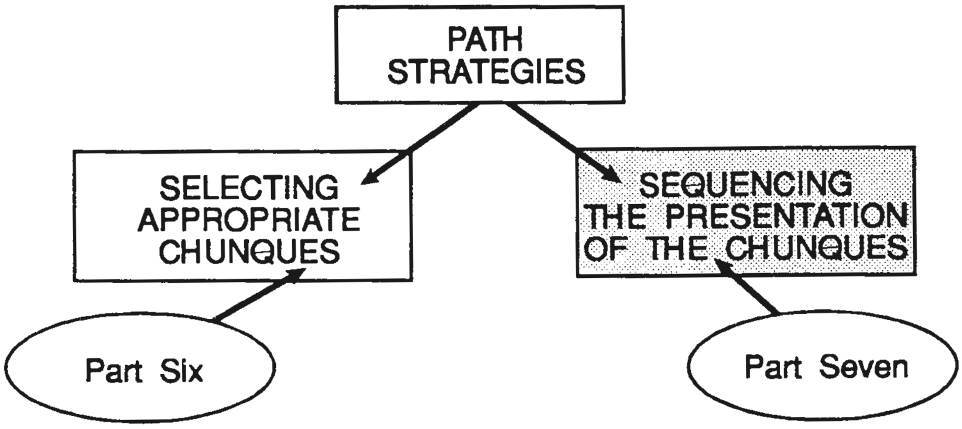
13 There is a fascinating discussion of the role of faculty in different academic cultures, which relates directly to this TTWTAKAAA problem in Clark, B. R. (1989). The academic life: Small worlds, different worlds. *Educational Researcher, 18* (5), 4-8.

PART SEVEN: SEQUENCING CHUNQUES IN A PATH

7.1 CURRICULUM MAPS

A central concern in Chunque-based learning system design is the creation of an appropriate path for each learner. This is one of the concerns that ensures the primacy of the student. For this reason, the propositions that guide the creation of a path are critical elements of the Chunque Theory. There are two of these critical elements. Each is founded on the notion that a path is comprised of Chunques, which are self contained learning experiences for meaningful pieces of subject matter. The first critical element is the selection of appropriate Chunques from the curriculum map to devise an optimal set of learning experiences to bridge the gap from the student's entry capabilities to the desired (or required) exit capabilities.[1] The second critical element is the sequencing of these Chunques into an ordered set of learning experiences that will unfold the subject matter in a learnable fashion for the student.



The development of a curriculum map from an experts' model and the selection of appropriate Chunques was explored in Part Six. The strategies for sequencing will be discussed here.

There are two parts to the sequencing problem. The curriculum map, which is an all inclusive educators' representation of the required exit capabilities, provides the source for the Chunques which are selected to make up a path. This array of Chunques must be organized into a framework that provides a teachable sequence of ideas. The first part of this chapter will look at several organizing schemes including prerequisite hierarchies, cumulation hierarchies, and elaboration hierarchies, which provide some constraints on the order in which the Chunques must be learned. The second part will examine ways to determine optimal sequences when these organizing schemes fail to prescribe the order in which the Chunques should be learned.

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1 Recall that *capabilities* are defined as a student's ability to accomplish something.

7.2 CURRICULUM MAPS AND SEQUENCING CHUNQUES

Let's assume that we have used some sort of course design prescriptions to transform the experts' model into a curriculum map that includes all of the chunques which define the required exit capabilities for the course. Note that these chunques (with a lower case c) are descriptions of the subject matter each learning experience in the curriculum map would contain.[2] The organization of the chunques in a *curriculum map* is based on the nature of the subject matter, not on considerations of how to carry these notions to a learner. That is, the curriculum map is intended to structure the ideas in the curriculum and their interrelationships in a way that makes sense to a beginning student. The chunques are clustered depending on the significance of these interrelationships.

While a curriculum map is an educator's transformation of the domain, it is not designed with a view towards unfolding the curriculum to a learner; it is not intended to prescribe the sequence of presentation of the Chunques (of instruction) to a student. It is intended to be a helpful way of organizing the chunques (of subject matter) into a representation of reality that will be meaningful to students.[3]

I used to refer to this as the Christmas Tree and the Balls Theory. It is a matter of emphasis. You can either teach the student what the Christmas tree is like and have them imagine their own ornaments, or you can teach them about the balls, and have them imagine their own tree to hang them on. A curriculum map is the Christmas tree upon which the students can hang the notions that make up a curriculum. It is not a road map that prescribes which of those notions should be taught in which order.

These chunques from the curriculum map have to be organized into a framework that will prescribe the most appropriate way to sequence them into a path. There are several currently popular organizing strategies that prescribe various ways of organizing subject matter. A variety of these are briefly described in the next few sections.

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2 Recall that a chunque is a specification for a piece of subject matter, while a Chunque is the learning experience that is used to teach that subject matter.

3 Reigeluth makes a distinction between a *content* map which defines how to organize content (this is like a curriculum map) and an *instructional* map which defines how to sequence content. This is from private communications during 1990.

7.3 THE REIGELUTHIAN ZOOM

Reigeluth developed a zoom lens analogy to capture the essence of a number of commonly used organizing strategies. His analogy suggests that we imagine exploring a domain as if through a zoom lens on a camera. To begin, let's look at the way many typical courses are organized, based on the conventional wisdom of our field. As Reigeluth explains it, instruction starts:

> ... with the "lens" zoomed in to the level of complexity deemed appropriate for the intended student population; and they proceed - with the "lens" locked on that level of complexity - to pan across the entire subject matter ...[4]

This view could be called a *pan* approach to content organization. The Chunques would all be developed at roughly the same level of detail, and the students would learn them one after the other. This is somewhat like course design based on the topics in a textbook. It does not seem to be a very good method, because it does not accommodate any broad overview of the domain or suggest any way of taking a closer look at more significant parts of the domain.

If this analogy is applied to studying the Mona Lisa, the students would look at various pieces of the painting, studying each to a level of detail that was considered appropriate for the particular students in the course. One piece after another would be viewed in a sequence that often reflects the hierarchical structure of an experts' model. The students would be left to discover on their own the great AHA! ... what they were studying was the Mona Lisa.

In the DACUM process, programs are typically developed following this model by picking one band and learning the Chunques (or even the tasks) in a sequence dictated by the structure of the DACUM profile. Students following this model learn each individual competency in great detail before moving to the next. Eventually, the students learn all of the competencies, often from a group of instructors in separate classes with little integration or synthesis. This can result in a very fragmented array of small, partial models which evolve in a haphazard way without intentional guidance from the learning experiences.

One observation is that most subject matter can be studied with the lens zoomed way in on the most minute details. For example, there is the observation from computer science that says "anything about computers can be explained in terms of bit-shuffling - but it might not be very useful." I suppose the entire cosmos could be explained in terms of quarks with charm, but that too may not be the most useful way of representing the universe to the average learner.[5] I seem to recall a number of courses from my public school days, especially in areas like social studies and psychology, that used this metaphor. I think in universities they are commonly called survey courses.

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[4] Reigeluth, C. M. (1983a). Instructional design: Wat is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates. (p. 342).

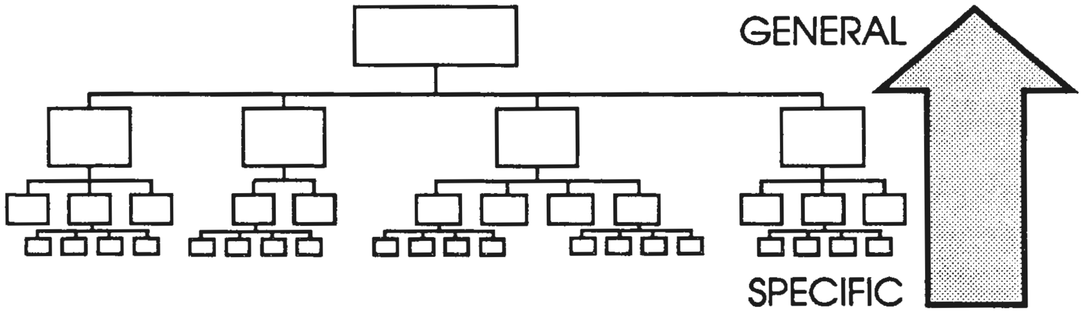
[5] Once again, it comes back to the matter of scale.

7.4 CUMULATION STRATEGIES

Cumulation strategies are derived from a different kind of content organization. The chunques are organized in a hierarchy that begins with the most detailed and specific notions (the *parts*) and gradually builds upon these notions to construct more general notions (the *whole*). This has been called the "bricks in the temple of knowledge" approach to learning. Reigeluth describes this with his zoom lens:

> Using a hierarchical approach, many instructional developers have used a sequence that in some ways resembles beginning with the lens zoomed all the way in and proceeding in a highly fragmented manner to pan across a small part and zoom out a bit on that part; pan across another small part and zoom out a bit, and so on ...[6]

Often, when dealing with larger portions of a domain, these "small parts" are taught by different instructors in different courses. Sometimes, the zoom lens analogy gives way to a series of Polaroids, snapshots of fragmented pieces that never quite coalesce into a unified whole. The emphasis is on the meatballs, if you will excuse the mixed metaphor. The student has to find his own spaghetti. This, I believe, results in limited understanding that is both fragmented and reductionist. I suspect this evolved from the behaviorist notions of Skinner and his colleagues, who seemed to view the world in an atomistic way.[7] But then again, there were no zoom lenses back then. The curriculum map for this type of organization could be a hierarchy with the most general ideas at the top, graduating to the most specific at the bottom. Instruction would begin with the most *specific* ideas near the bottom of the hierarchy and work upwards towards to more *general* ideas. This could also be expressed as a parts-to-whole sequence.



The study of the Mona Lisa would begin with the lens zoomed as far in as possible and then panned around to explore such things as the brush strokes, the bits of color, or the tip of the nose. Over the course of instruction, the lens would be slowly zoomed out and panned to reveal more and more of the painting, until, in the end, the whole image would be visible. This is different from the first strategy in that the lens is progressively zoomed out over the course of the instruction. In the pan strategy, there is a very good chance the lens would never zoom at all.

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6 Reigeluth, *Instructional Design: What is it*, (p.342).

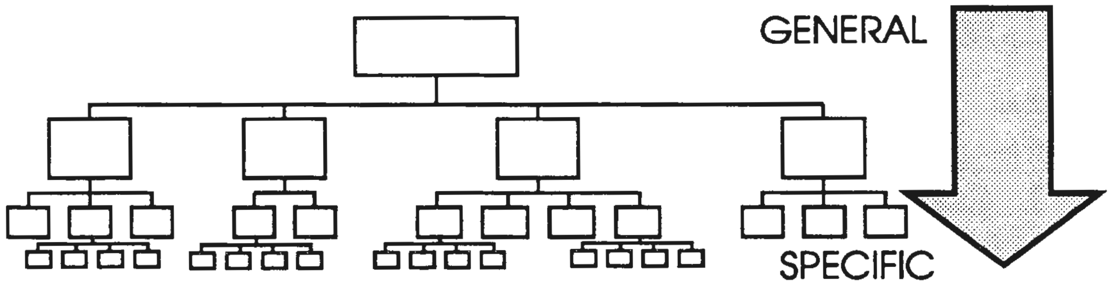
7 Skinner, B. F. (1971). *Beyond freedom and dignity*. New York: Knopf.

7.5 ELABORATION STRATEGIES

Bruner had it figured out, with his spiral curriculum, and the notion that you can teach anything in some intellectually honest fashion to any student at any age.[8] What a powerful idea! When we add Minsky's mental models to Reigeluth's zoom lens and Bruner's spirals, we can come up with some pretty good strategies for finding an appropriate path to make things teachable. *Elaboration* sequences start with the lens zoomed all the way out, to give an initial view of the whole Mona Lisa, so the students can grasp the most general idea of what it is. As Reigeluth expresses it:

> A person start with a wide-angle view, which allows him or her to see the major parts of the picture and the major relationships among those parts (eg., the composition or balance of the picture), but without any detail. The person then zooms in on part of the picture. ... After having studied those parts and their interrelationships, the person could then zoom back out to a wide angle view to review the other parts of the whole picture and to review the context of this part within the whole picture.[9]

This sounds a lot like the meaning and understanding that Minsky, Norman, and Gleick are talking about. This elaboration hierarchy starts with the most simple and general ideas at the top, and graduates to more complex and specific ideas at the bottom. However, in elaboration, the instruction starts with the most *simple and general* ideas at the top, and works downward toward the more *complex and specific* ideas at the bottom. It is a whole-to-parts sequence, somewhat like the cumulation approach turned upside down:



This zoom lens analogy illustrates only one part of the Elaboration Theory, but it grasps the essence of the sequencing strategies that are prescribed to unfold the domain to the students.[10] The power of the Elaboration Theory derives from the rich array of strategy components that are overlaid on the fundamental approach of the elaborating sequence from wholes to parts.

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8 Bruner, J. S. (1966). *Toward a theory of instruction.* New York: Norton.

9 Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates. (p. 340).

10 See Reigeluth and Stein, *Elaboration theory*, for a more complete explanation.

7.6 PREREQUISITE HIERARCHIES

One of the earliest prescriptions for course organization to come from the field of instructional design was the prerequisite strategy proposed by Gagne and Briggs.[11] *Prerequisite* hierarchies organize learning experiences so that each new lesson builds on the previous ones. For example, learners must know how to add before they can master multiple digit multiplication. These strategies are designed to ensure that all the capabilities that students must have in order to understand the current topic have been previously learned. Thus prerequisite sequences are valuable only if new notions depend on an understanding of previous ones, such as in mathematics. Prerequisite strategies do not provide guidance for content that is related in other ways, but do provide *essential* guidance when subject matter does fall into a prerequisite hierarchy. It seems that the more detailed and specific the perspective, the more the subject matter falls into prerequisite hierarchies. Often, prerequisite sequences are necessary within a more global cumulation or elaboration structure. As the Reigeluthian lens is zoomed out, relationships among various ideas seem to fall into other kinds of structures, and the sequencing possibilities become far more varied.

Prerequisite strategies cannot be easily expressed through the zoom lens analogy. Building the pyramids is probably a better metaphor. It would seem that the bottom blocks should be in place first. But if you want to build a complex of pyramids, prerequisite strategies do not explain which one to build first.

If we view a subject matter domain as a prerequisite hierarchy, the implied order or sequence might be only an artifact of the hierarchical structure itself, and not the reality of the situation. Bloom sees this problem as:

> For some courses, we find that the learning tasks are typically taught (and learned) in a particular order, but that what is learned does not require that order. That is, the different learning tasks do not require each other and they could be learned in many different orders - and could even be learned in random order.[12]

Note that prerequisite sequences do *not* depend on such things as a whole-part relationship or on the complexity of the notions, but only on a "need to know."

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11 Gagne, R. M., & Briggs, L. J. (1979). *Principles of instructional design* (2nd ed.). New York: Holt, Rinehart, Winston.

12 Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill. (p. 26).

7.7 SOME OTHER STRATEGIES

There are a number of other common sequencing methods used for organizing content that does not appear to fit a hierarchical structure. A *chronological* path sequence lays out the Chunques in a time sequence, as is common in historical or biographical works. However, use of this sequence should be tempered with a consideration of whether it aids in the development of meaningful understandings for the learner. I suspect that the structure of the mental model developed by many people does not match a chronological sequence, but rather is based on other more meaningful relationships between the notions in the domain.

Closely related to a chronological sequence is a *procedure step* sequence, where steps in a procedure must be performed in a particular order. However, because the steps must be *performed* in a particular order does not imply that they must be *learned* in the same order.[13] None the less, the competency that is finally developed must recognize the order of performance. If, for instructional reasons, the steps are learned out of sequence, additional instruction might be needed throughout the learning experiences to insure that the steps are internalized into an appropriate model.

A variation on this is the *reverse chaining* sequence where the steps in a procedure are learned in the opposite order from that in which they are performed. The same concerns with having to later learn the sequence necessary to perform the procedure applies to reverse chaining.

This array of organizing strategies is by no means exhaustive, but is intended to provide an overview of some of the methods prescribed to structure learning experiences to make them more teachable.

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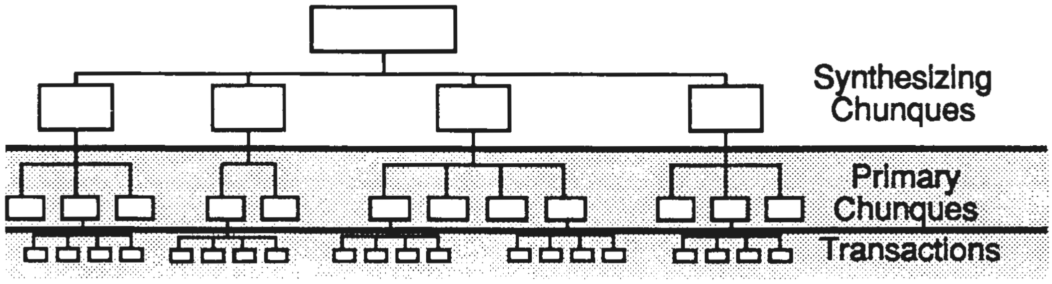
[13] Bloom, B. S., *Human characteristics.* (p. 27). Merrill, P. F. (1987). In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 141-173). Hillsdale, NJ: Lawrence Erlbaum Associates.

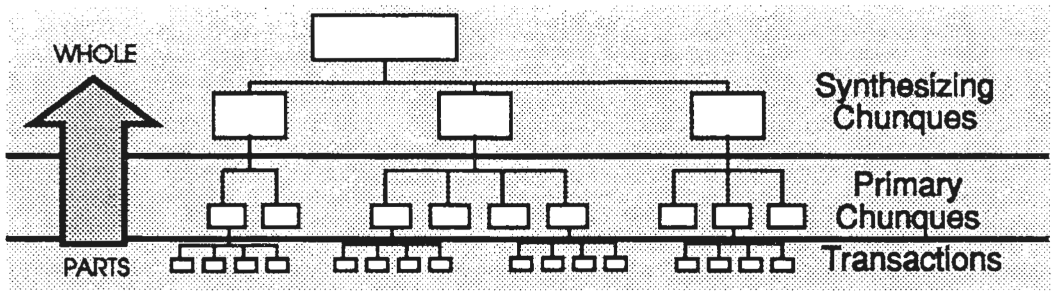
7.8 SOME CHARACTERISTICS OF ORGANIZING STRATEGIES

Over the course of this discussion of different strategies for organizing content so that it will unfold in a meaningful way for novice learners, we have looked at several different structures. Here is a brief view of the relationship between primary Chunques, synthesizing Chunques and transactions within each of these structures.

The DACUM process, by its very nature, focuses attention at the primary Chunque level, because that is what the participants are specifically asked to identify: what are the smallest "competencies" or "things that you do" in their occupations. Then they (usually through a task analysis process) identify the steps within these competencies. The competencies become the primary Chunques, the steps the transactions within Chunques. Typically, very little attention is paid to synthesis or synthesizing Chunques. This structure of Chunques might look somewhat like the shaded part of this figure:

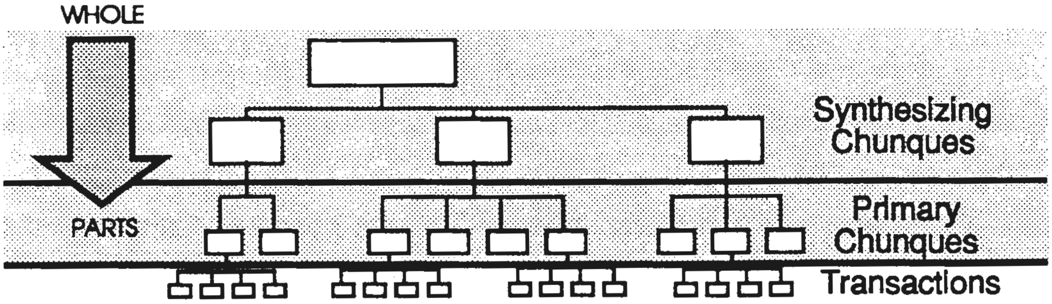


The cumulation approach starts with very fine grained bits of knowledge and works up to a broader picture with a series of parts-to-whole relationships The upper level of this structure, the "whole" level, might be what the Chunque theory calls primary Chunques, with the "parts" being the transactions within the primary Chunques. The problem with this approach is that there might be a tendency to reduce the emphasis on (or even ignore) the synthesizing chunques. This might result in a graphical representation similar to the DACUM representation above, except that the cumulation structure defines an order of presentation that is lacking in the DACUM: a parts-to-whole unfolding of the domain:



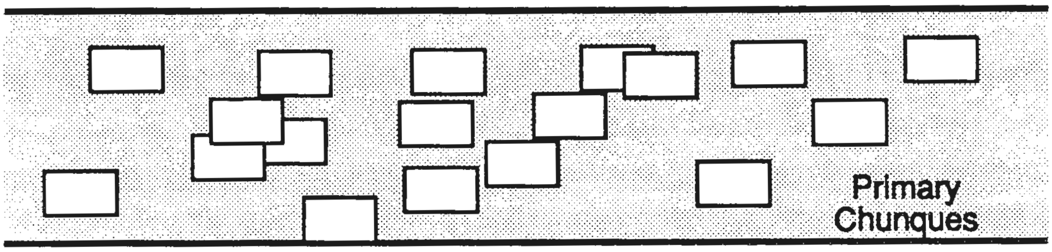
7.9 FURTHER ORGANIZING CHARACTERISTICS

An elaboration structure is not quite like an upside-down cumulation structure. Elaboration structures start with a holistic view of the domain, in a whole-to-parts relationship. I view this as an initial emphasis on synthesizing Chunques. This set of synthesizing Chunques is then developed *down* to the level of the primary Chunques, like this:



I believe the power of this approach resides in the initial emphasis on integration and the final attack on the primary Chunques, the "smallest meaningful collection of notions" from the top down.

In the design of the PASSPORT system, we had not thought through the implications of these instructional structures and their relationship to primary and synthesizing Chunques. In fact, at that time we did not recognize any distinction between the two ... a chunque was a chunque. Thus the PASSPORT organizing structure might be represented like this:



This is much more of a mix and match approach, but I don't think it works too well unless the notions within each Chunque are both relatively independent of one another and sort of "uni-level", with no elaborate vertical parts-to-whole relationships. This was indeed the situation with the life skills Chunques in the PASSPORT system.

7.10 PRIMARY CHUNQUES

Where does the notion of a primary level Chunque fit into the instructional structures (or curriculum maps) represented by DACUM, cumulation, elaboration, and PASSPORT strategies? Well, I think, in an oversimplification, the essence of these structures could be viewed in this way: The DACUM process focuses on the primary Chunques, with secondary interest in transactions for steps. The top is lopped off of this representation: synthesis is largely ignored, and the various competencies represented by the primary Chunques are dealt with in an isolated manner.

The cumulation representation is similar, but with the possibility of more levels below the primary Chunques, and an implied order of unfolding, from detail to generality. Synthesis is still lopped off.

Elaboration stresses synthesis, and once again there is an implied order of unfolding, from whole to parts. The focus of this approach tends to lop off the bottom: the emphasis is on the macro-level strategies, and the primary Chunque level, the smallest meaningful pieces of content, can be seen as residing at the bottom of the structure: the primary Chunques are the "level of complexity deemed appropriate for the intended student population" seen as an end point in the instruction.[14]

The PASSPORT system, somewhat less sophisticated in its analysis of curriculum map structure, was a single level structure consisting only of one kind of Chunques which could be selected in a mix and match strategy, without recognition of much in the way of structural constraint. The notion of among-Chunque integration was largely ignored.

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14 Reigeluth, *Instructional Design: What is it*, (p.342).

7.11 CUMULATION OR ELABORATION FOR PATH STRATEGIES

Let's look at the fundamental differences between a cumulation and an elaboration framework. A cumulation sequence prescribes a *part- to-whole* sequence of Chunques within a path, where the parts are learned before the whole. An elaboration scheme prescribes a *whole-to-parts* sequence, where the simplest form of the ideas are presented first, followed by more detailed and specific knowledge. The whole is learned before the parts.

The Chunque Theory proposes that an elaboration sequence is more appropriate for learning system design, because the most global view of a domain with appropriate linkages between the Chunques can be developed from the simple and general ideas. This simple but correct model can be filled in and expanded into a more comprehensive structure as new and more specific ideas are incorporated, without changing the basic structure. If a cumulation approach is used, the learner is denied the "big picture" of the relationships between the ideas until near the end of the sequence, when the specific small parts are assembled into a meaningful whole. I call this the great AHA, which may be fine for detective novels, but is less appropriate for learning system path design.

Of course, in some instances the mystery surrounding the great AHA can be a powerful motivational tool, as in discovery learning. However, close attention must be paid to design considerations which provide adequate cues to the learner to steer the discovery in the desired direction. *Joyce and Weil* discuss the importance of adequate direction and planning in cumulation paths in *Models of Teaching.*[15]

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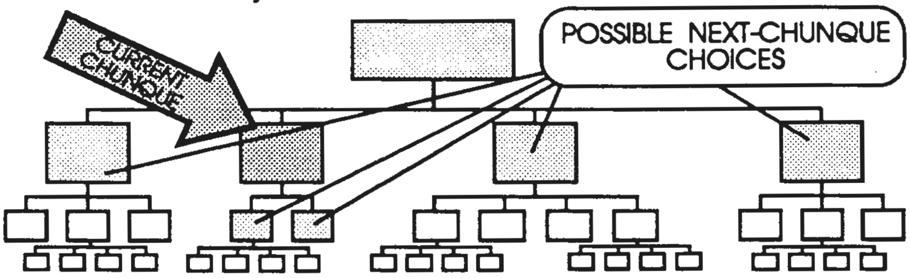
[15] Joyce, B., & Weil, M. (1980). *Models of teaching* (2nd ed.). Englewood Cliffs, NJ: Educational Technology Publications (pp.61-74).

7.12 CONCERNING CONSTRAINTS

We have looked at several plausible methods of organizing the Chunques in a curriculum map that could provide guidance in developing a path, including pan, cumulation, elaboration, prerequisite, chronological, and procedure steps. Each of these strategies result in an organizing structure that is based on some sort of relationship among the Chunques. In some cases, the nature of these relationships are clearly spelled out, in others less so. But one important point about these between-Chunque relationships is that they provide *constraints* on which Chunques can be learned next.[16]

For example, in an elaboration hierarchy, students are constrained to first learn the most general and simple Chunques. In a prerequisite hierarchy, students are compelled to learn Chunques that are considered to be required in order to understand the next Chunque. Structures constrain some, but not all, of the next-Chunque choices. An elaboration hierarchy, for example, constrains the student to learn either one of the next most detailed Chunques (in a vertical path move) or one of the parallel Chunques (in a horizontal path move), but it does not suggest which of these possible choices is optimal. This diagram illustrates which of the Chunques are available to a student under the Elaboration Theory:



In general it would appear that of the examples given, the chronological and procedure step organizing strategies would provide the most constraints on next-Chunque choices, while the elaboration, cumulation, and pan structures would provide less constraints (or, expressed another way, less prescriptions or guidance). The degree of constraint depends on the nature of the instructional organizing structure.[17]

I have, over the last few sections, provided guidelines for macro-logistic path strategies that constrain next-Chunque choices. When these have been exhausted there will still be circumstances where a range of next-Chunque options exist - where no prescriptions exist at this time for selecting which of the valid next-Chunques to select. Nobody talks about this very much. In his keynote address to the Association for Media and Technology in Canada, Merrill stated, "We have no prescriptions for course organization ... what are the rules ... what are the prescriptions ... we must systematize the underlying principles ..."[18]

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16 This is discussed in more detail in Part Ten: Mnets.

17 The clustering strategy described in Part Six is another way to define relationships among Chunques which can be used to guide in sequencing Chunques.

18 Merrill, M. D. (1989, June). Paper presented at the annual convention of the Association for Media and Technology in Canada, Edmonton, Alberta.

7.13 LEARNER CONTROL AND SYSTEM CONTROL

Here is a suggestion. If the instructional organizing strategy does not provide a prescription among next-Chunque possibilities, let the student decide.

This is an instance of my general prescription for learner control versus system control. Conventional wisdom states that, for instructional decisions (as in individualizing strategies), students tend to make the wrong choices,[19] while for motivational decisions (as in personalizing), it is difficult to see what a "wrong" decision might be. Stated another way, it might be risky to let students make individualizing decisions, especially when this can be so important in determining the effectiveness of the instruction. When in doubt, let the system decide. This is fine when the system has some basis for making a prescription for a particular next-Chunque choice. However, as noted in the previous section, there are many cases where the constraints on next-Chunque choices imposed by the structural framework of the organizing strategy do not limit the choice to one particular Chunque, but only to one of a group. In this situation, the system cannot provide a prescription regarding what the student should learn next.

This difficulty stems from our limited understanding of the many kinds of relationships that can exist between Chunques The relationships guiding the organizing strategies discussed earlier in this chapter are quite limited. Now, there is a possibility that the reason the organizing strategy for many of these common schemes cannot provide guidance among next-Chunque possibilities is that no one has recognized some important reasons for choosing one over the other, but until someone does ... what should we do? In this situation, let the student decide. It might be very important from an *appeal* or motivational perspective.[20]

Part Ten: Mnets provides some insight into other kinds of relationships that might prove valuable in deciding what an optimal sequence of Chunques would be.

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19 See these articles for a discussion of learner control: Ross, S. M., & Morrison, G. R. (1989). In search of a happy medium in instructional technology research: Issues concerning external validity, media replications, and learner control. *Educational Technology Research and Development, 37* (1), 19-33; Tennyson, R. D., Welsh, J., Christensen, D. L., & Hajovy, H. (1985). Interactive effects of content structure, sequence, and process learning time on rule-using in computer-based instruction. *Educational Communications and Technology Journal, 33*, 213-233; and Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

20 This prescription is based primarily on John Keller's ARCS model for motivation by design. Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum Associates.

7.14 MANAGING PATHS

There is a major problem with managing all of this. We have talked about different *selection strategies* to decide what Chunques from a curriculum map to include in any particular student's path, different *organizing strategies* to determine in what possible order these Chunques could be sequenced in the path, and which of these possible orders is optimal for effectiveness and appeal. And this only considers an anticipatory path. Things get much more complex when we have to deal with adaptive routes created as a result of diagnostic testing and changing student interests. How do we manage all of these things to create a customized student centered learning system?

Computer managed learning has been touted as the answer to these problems, but when you begin to consider the size of the database that would be required to keep track of all of this it would be enormous. Even if a computer managed learning system could keep track, consider this: how could it tie them all together? Back in Part Two I discussed understanding and meaning. These notions are grounded in the idea of interrelationships and context. If a course is designed around the primary-level Chunques with the major portion of the instruction residing within these Chunques, how can these ideas be linked to the other Chunques to provide understanding? It would depend on which other Chunques were included in the particular path. And how could the Chunques in one path be linked to more remote arrays of Chunques in other paths from other courses to provide context and meaning? This is a difficult situation. I have no good answer.

It would seem that the benefits of creating customized instruction from an array of mix and match Chunques must be balanced against the difficulty in providing learning experiences that explicate the links among these Chunques. A thorny issue. Or, as they say, a subject for further research.

Earlier, I spoke of the communion between humans and technology in education. This is one area where the pattern recognition ability of the human mind can clobber the power of a computer. I would suggest that we may be able to create a computer managed learning system that would keep track of which Chunques the student had learned and prescribe which Chunque to learn next, but it would still need a live teacher or mentor to examine what pieces the student had learned and provide the contextual knowledge that is so crucial in gaining meaningful understanding.

I'll come back to this in Part Ten.

7.15 HOLOGRAPHS

A holograph is a different kind of image from a photograph. What most people think about when they think about holographs at all is an eerie three dimensional image floating in space (or on the front of a VISA card) that seems to allow them to look around corners. But a holograph has another interesting property.[21] If you take a hologram of a scene and cut out one small piece of it, that piece still contains the entire scene.

If Reigeluth had used a holographic camera to capture the image of the Mona Lisa, it would have been impossible to cut the piece out of the hologram that contained just her nose. Any cut-out piece would still contain the image of the entire Mona Lisa, nose and all. If the piece was large, the image would be fairly detailed. If the piece was small, the detail would be less distinct. The resolution would be reduced.

When we are talking about instructional logistics, I like what this metaphor adds to the Reigeluthian zoom lens. Actually, to get complicated, it would be nice to have a combination of Reigeluth's zoom lens and my holograph, so we could zoom in when it was appropriate to isolate a small part of the picture, but still have the whole thing there lurking in the background. Sort of like tunnel vision.

A holographic metaphor begins with a broad but fuzzy view where the details and intricacies are lost. The holographic image lacks detail, but captures the feeling of the vision, the colors, the outlined shapes, the relationships. Then, slowly, as the size of the hologram increases, the holographic image becomes more detailed.

One nice thing about analogies is that they never quite do the job, but if you can live with the notion of a zooming holograph, then you will have an easier time dealing with my vision of instructional logistics. This notion of a zooming holograph fits quite nicely with my thoughts about mental models and meaningful understanding.

What I propose we should seek in designing a path through a network of learning experiences is a way of creating a holographic image of the total domain that might begin a little blurred, but still captures the whole picture. Then we can zoom in, pan around, or zoom back out to explore the nooks and crannies and look around the corners of the scene, but the whole picture will still be there to provide the context the students need for meaningful understanding.

This is my new mindframe, a mindframe like those that Shavelson suggests can provide evidence that may "confirm, construct, challenge, or change" the way we deal with the world of education, and provide a valuable link between theory and practice.[22]

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21 Actually, you can't see around corners on the VISA card ... only on projected holograms.

22 Shavelson, R. J. (1988). Contribution of educational research to policy and practice: Constructing, challenging, changing cognition. *Educational Researcher. 17* (7), 4-11.

7.16 SYNTHESIS

In this Part the focus was on determining what methods or strategy components can be used to determine an optimal sequence of Chunques in a path. Once an appropriate array of Chunques for a path has been selected, the learning system designer is faced with the challenge of arranging them in a manner that will unfold the domain in a meaningful way for novice learners.

Several conventional approaches to this sequencing problem were presented, including cumulation, elaboration, prerequisite hierarchies, and chronological sequences. Some of these structures were illustrated with Reigeluth's zoom lens analogy. A holographic metaphor was developed as an alternative way of viewing an unfolding sequence. This will be expanded in Part Ten: MNETS.

Finally, the notion that these various organizing structures placed constraints on the sequence of next-Chunque choices was introduced, and the implications of these constraints regarding learner or system control was discussed briefly.

This leaves us with a collection of strategies for determining the nature of the kinds of goals in a program, relating these to a subject matter domain, and transforming this domain into an instructional organizing structure that can guide decisions for sequencing the Chunques in a path or route. In the next section, Part Eight, the relationship between path construction, learner progression along a path, and assessment of student accomplishments will be explored.

PART EIGHT: ASSESSMENT AND THE PURSUIT OF EXCELLENCE

8.1 INTRODUCTION

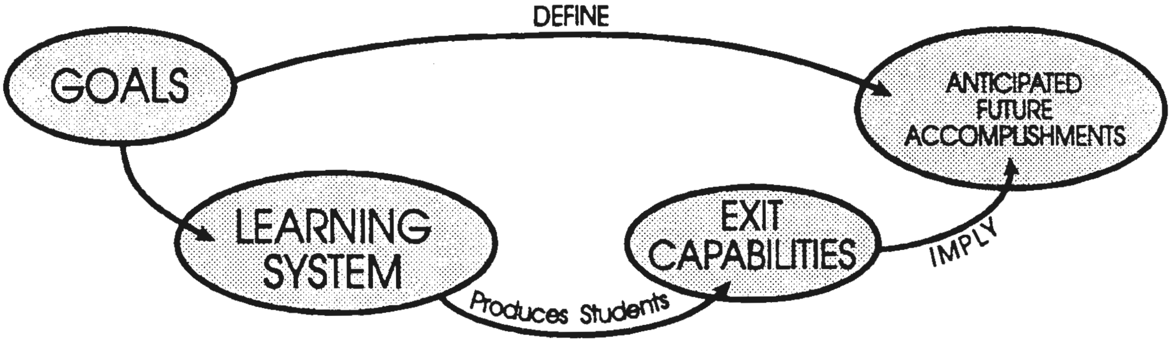
It may seem strange that assessment is included in a book about managing learning systems: what does assessment have to do with management strategies? Well, assessment of some sort is essential in managing the progression of the learner through the system. For example, the assessment of entry capabilities is needed to determine if the student has the required prerequisite competencies to succeed in the Chunque. The mastery level chosen determines in large part the likelihood of continuing success in successive modules. The diagnostic informative testing is needed to determine whether students have learned, and to determine what amount and kind of remediation is required. Criterion referenced assessment of accomplishments is central to the notion of student centered learning systems based on chunques of content.

This section does not deal with testing per se, but with the nature of the assessment measures needed to manage instruction and student progression, and with a close correspondence between the value laden curricular goals and assessment measures, which is critical if we are to accurately determine if what we are teaching is what is being tested, and consequently, what is being learned. Also there is a concern in competency based education with the minimum standard becoming a maximum. How can we design a system that fosters the pursuit of excellence beyond the minimum standard for mastery? These are the concerns addressed in this chapter.

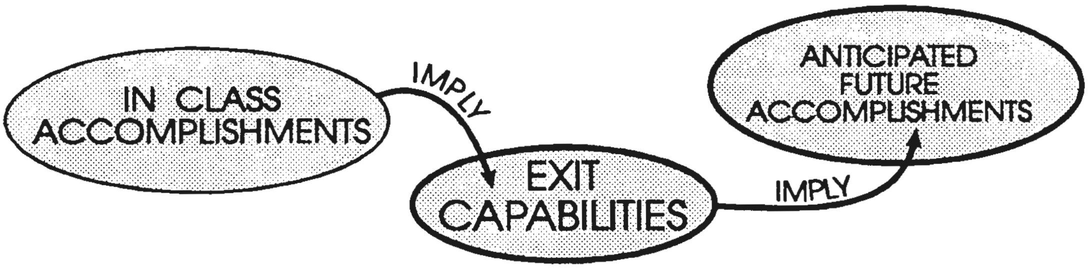
8.2 WHAT IS A LEARNING SYSTEM SUPPOSED TO DO?

Let's look in a most general sense at what a learning system is intended to do. The intention of a learning system is to produce students who are expected at some time in the future to accomplish something. Just what their anticipated *future accomplishments* are is specified by the goals in the value-laden curriculum. This curriculum is in turn specified by the stakeholders in the program.

We have, then, a set of value laden goals which define anticipated future accomplishments. A learning system almost fills the gap between the goals and the future accomplishments. But not quite. A learning system can at best produce students who, at the end of the learning experiences, have the capabilities necessary to produce the anticipated future accomplishments. A learning system turns out capable graduates.



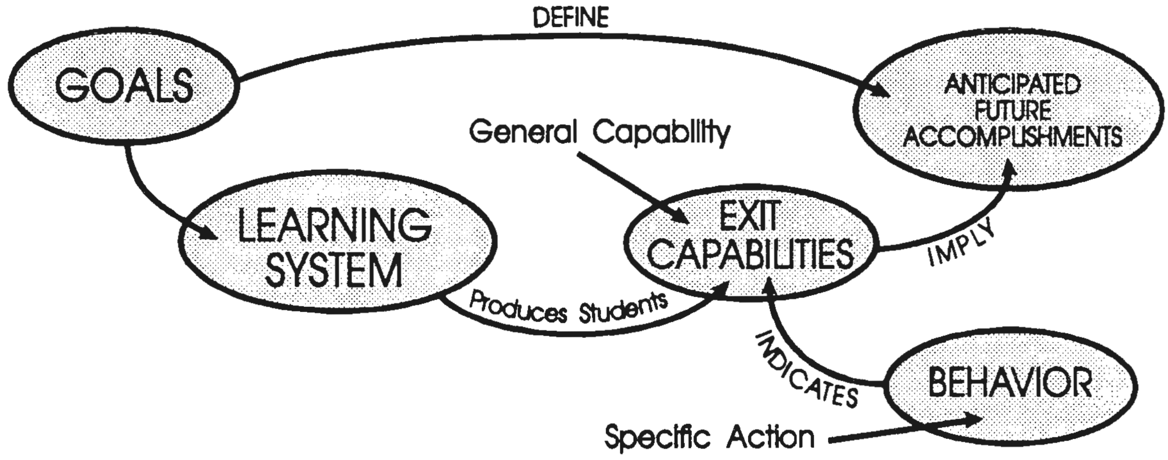
How can we be certain that a student possesses the required capabilities? I do not think we can. At best we can assess whatever the student accomplished *during the learning experiences* and from this *imply* that the capabilities are there. Assessment measures (eg., test questions) are used to assess student accomplishments during instruction that are assumed to indicate capabilities. These capabilities are designed to lead to anticipated future accomplishments (after leaving the instruction) that match the value laden goals of the stakeholders.



8.3 ACCOMPLISHMENTS AND CAPABILITIES

When a student completes a program, we want him or her to have the capacity to accomplish something that could not be accomplished before the instruction. Behavioral objectives are one example of a way to express what these things are, and to specify them in a measurable fashion. They specify performance outcomes. Once the student can convince the instructor that he or she can perform these behaviors, the student is effectively certified as competent.

However, I believe this example presents a couple of problems. George Gropper states that our instruction is only as good as our analysis.[1] Let's analyze things a little more closely. When a student completes my instruction, I want him or her to have the capacity to do much more than what I can measure with some sort of performance objective. To me, the performance objective, especially when it is very tightly specified, can at best only give me an indication that the student can demonstrate a specific behavior. The rock solid behavioral objective school of thought is based on this: can the student demonstrate the required behavior?



Ken Carlisle suggests that we use the term *capability* rather than behavior to define what it is that we want the students to gain from the instruction.[2] He points out that we want to provide the student with the capability to accomplish something. I would like to take this line of reasoning a bit further. To me, the term *capability* suggests that the student has a more general ability that goes beyond the required behavior. The behavior is only an *instance* of the more general capability to accomplish a number of things, the ability to go beyond the behaviors we assess. I believe this is an important distinction, especially in light of the discussion on meaningful understanding and creating mental models.

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1 Gropper, G. L. (1983a). A behavioral approach to instructional prescription. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 101-161). Hillsdale, NJ: Lawrence Erlbaum Associates.

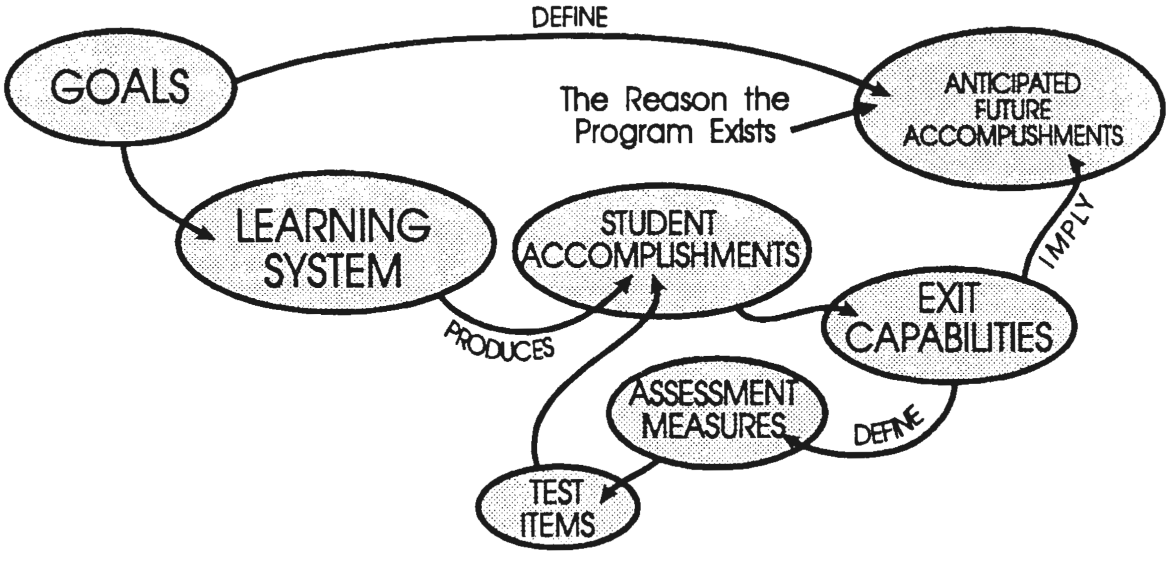
2 Ken Carlisle presented this view at the Canadian Centre for Learning Systems symposia in 1989.

8.4 CAPABILITIES

I will use the term *capability* to define the broader expectations that I hold as the outcome of instruction. I want my students to gain *capabilities*. I am not sure I can adequately assess whether the student possesses these capabilities, but I am certainly going to try.

How might we tell if the student has gained these capabilities? By assessing their accomplishments. An *accomplishment* is an observable and worthwhile result of instruction. I am introducing this term to clarify that what I am after goes beyond a simple observable behavior. I think this notion becomes more significant as we move along the Three Souls continuum toward the Education-to-Be end. Behavioral objectives and competencies were developed to assess training near the Training-to-Do end of the continuum. They work very well for assessing welders. But perhaps not so well for addressing Princes or philosophers.

For now, I will use the term *accomplishment* to refer to what it is that the student demonstrates as a result of the instruction. I will use the term *capability* to refer to what it is that I want the student to gain from the instruction. And I will use the term *assessment measure* to refer to a representative example of the kind of measuring tool I will use to determine if I have some confidence that the student has mastered whatever it is that is necessary to gain the intended capability.



A competent graduate is one who has convinced me (through my use of an appropriate array of assessment measures) that his or her accomplishments are indicative of mastery of whatever is necessary to gain the capability that is intended by the value-laden curriculum. This assures two critical things. First, that the goals correspond to the capabilities, and second, that the assessment measures *do* measure observable accomplishments that can go far beyond what reductionist test questions can indicate about student capabilities.

8.5 CERTIFICATION OF MINIMUM COMPETENCE

The fundamental notion behind assessment strategies in learning system design is to determine whether a learner has developed sufficient capabilities to be certified as competent. This notion is derived directly from the competency based education movement and mastery learning.[3]

Learning systems are comprised of Chunques which are defined as the smallest certifiable pieces of content. A course or program is created by assembling a collection of suitable Chunques into a customized path for the learner. The notion of assessing learner competence in a course or program depends on certifying learner competence in each and every Chunque that is deemed to be an *essential* part of the courses.

This idea of *essential Chunques* is grounded in the curriculum strategies of competency based education. Competency based programs are designed so that all learner capabilities necessary to perform a job (or act as a competent graduate) are identified, taught, and mastered by each learner. In many cases a concerted effort is made to weed out non-essential content to make the program more efficient, especially in training situations.[4]

The Chunque Theory, since it deals with Education-to-Be and Sagacity-to-Know as well as Training-to-Do, builds on these notions to devise a system applicable to a wider range of program goals. Essential competencies or learner capabilities must still be carefully identified, as discussed in Part Three: Representing a Curriculum, but in addition a range of other desirable but non-essential competencies can also be identified. These non-essential capabilities are classified as *enrichment* capabilities, and are developed into enrichment Chunques. This results in a profile of Chunques that can be classified into these two categories.

Essential Chunques are those that the learner must master in order to perform whatever accomplishments are intended by the program goals. *Enrichment* Chunques are those that provide a more diverse understanding that goes beyond the basic minimum requirements.

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3 Bloom, B. S. (1976). *Human characteristics and school learning.* New York: McGraw-Hill.

4 This position is supported by many of the member institutions in the Eastern Region Competency Based Education Consortium.

8.6 THE ESSENTIAL ELEMENTS

As we have seen, for certification of competence in a program, learners must demonstrate mastery of each and every essential Chunque in the curriculum. By definition, essential Chunques encompass the ideas that each learner must master. If the learners do not need to demonstrate mastery of these ideas, then the Chunques must not be essential.

What happens in the worst case scenario where a learner excels at every essential Chunque except one? Well, there was once an airline pilot who achieved a ninety-nine percent average in flight training. This pilot could loop a 747 and not wake up a single passenger. In the simulator, regardless of what the instructors devised as the most intractable problems, this pilot could save the day. Many airlines tried to recruit this pilot, as not many achieved a ninety-nine. His career was extremely short. Nobody recognized that a ninety-nine average was meaningless if the other one percent happened to be something critical. This pilot could just never quite master lowering the undercarriage (he missed the class; his car broke down).

In competency based learning systems the determination of competency is based not on an average mark across Chunques, but on attaining minimum acceptable competence in each and every essential Chunque.[5] Later we will look at precisely what constitutes mastery in particular situations, but for now the critical notion is acceptable performance in every essential Chunque. If the learner flunks one essential Chunque, certification cannot be granted.[6]

Enrichment Chunques are designed to promote achievement beyond minimum competence. If essential Chunques are the "need-to-know" pieces, enrichment Chunques are the "nice-to-know" pieces, not essential for a minimally competent graduate, but useful in accomplishing beyond the minimum. If our pilot trainee can be remediated to success in lowering the wheels, competence in getting you there is expected. Optionally, this pilot must master the peculiarities of flying either a helicopter, a jet, a crop spraying plane, or a float plane. To be a pilot, at least one of the above is probably required. Ideally, for an airline pilot, it would be nice to be competent in providing in-flight trivia announcements or to fly smoothly enough not to spill the drinks ... but not essential.

The role of optional and enrichment Chunques in overall learning system design increases as the curriculum moves from the Training-to-Do end of the curriculum continuum to the Education-to-Be end. To overstate the case, at the extreme of Training-to-Do, there should be very few non-essential ideas in the program, while at the Education-to-Be extreme it is possible that almost everything would be optional or enriching.

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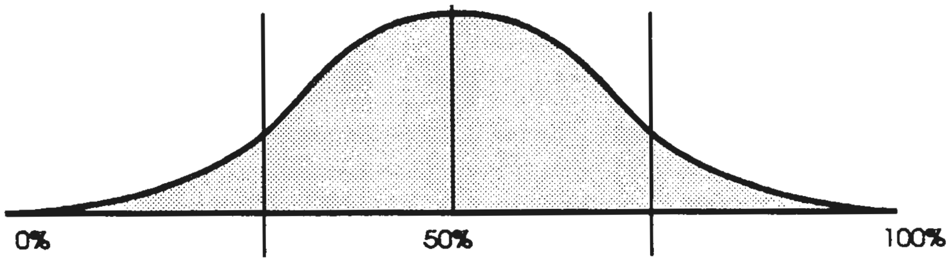
5 Millman, J. (1989). If at first you don't succeed: Setting passing scores when more than one attempt is permitted. *Educational Researcher, 18* (6), 5-9. Millman gives a persuasive set of arguments for not certifying someone who is a marginal flunker.

8.7 THE ASSESSMENT AND CERTIFICATION PROBLEM

A learning system described in the previous pages, comprised of essential, optional, and enrichment Chunques, implies that certification of mastery is a go/no-go thing. The learner either achieves mastery or does not achieve mastery in any particular Chunque. This notion is central to competency based education schemes. This notion also causes problems. It tends to codify and promote mediocrity. Let's explore this problem.

Learning systems have to address the issues of assessment of learner performance, grades, certification, and the conflicting demands of criterion referenced systems and normative based systems. In training situations, these problems are minimized, because learning systems for Training-to-Do are usually designed around specific competencies, and assessment strategies can be designed in a relatively straight forward fashion to measure these competencies using criterion referenced evaluation. These systems measure the performance of each learner against a fixed standard. The goal is to create a learning system where every student masters the required competencies to the criterion level. The goal is that everyone should succeed (or "pass the course", which in these systems often means attaining minimal certification standards). I call these *cooperative* grading systems, because students are inclined to help each other master the work.

In public education, colleges, and universities, however, there is a tradition of normative assessment strategies that evaluate the performance of each learner relative to the others. I call this *competitive* grading, because the students are inclined to beat out their fellows for a limited number of passing marks.[7] Normative assessment systems are criticized because there is no fixed standard of capabilities against which to measure the performance of each learner. In more hostile environments, normative assessment becomes a crap-shoot because the learners often do not know what the required performance standards are. This has been called the "pass the best and flunk the rest" system. In graphic terms, the ideal spread of grades under a normative grading systems looks like this, and half the students flunk:



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[6] Benjamin Bloom discusses the consequences of "passing through" failing students at some length in Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13* (6), 4-16. In this article, Bloom suggests that there are a number of critical attributes of failed mastery learning programs. This is one of them.

[7] We have all heard the horror stories of law students cutting the pages out of library reference books to prevent other students from having access to essential resources.

8.8 COMPETITIVE AND COOPERATIVE ASSESSMENT

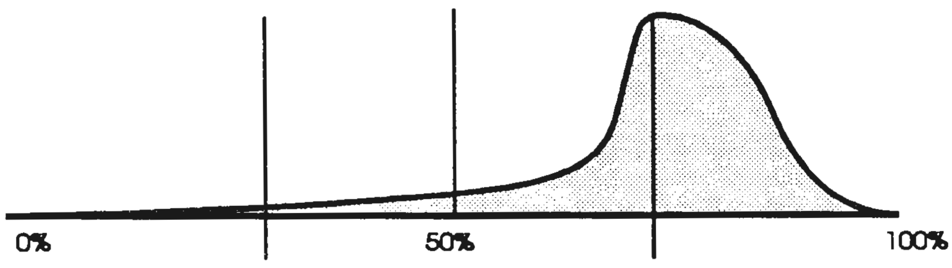
Competency based systems seem at first look to be both fair and intuitively "correct." After all, measuring the performance of a learner relative to a fixed target that is known ahead of time allows all of the learners to know what is expected of them, and provides, after the assessment, an honest and equitable picture of where they stand and whether they successfully mastered the capabilities or not.

On the other hand, some competency based systems do not reward the student who does better than the others. Student often demand a competitive grading system that rank orders them one against the other. Strangely, it seems it is not always the better learners who want this.

A major dilemma for the learning system designer is to strike a compromise between competitive and cooperative evaluation systems, which are often viewed as incompatible. Over the next few pages we will look at some possible solutions.

Let's take a closer look at criterion referenced evaluation and the certification of competence that were introduced on the previous page. The object of these techniques is to ensure that every student has mastered the essential ideas, the required capabilities, that are deemed necessary to be a successful graduate. It must be clearly understood that these standards are the *minimum* standards of mastery. Not the desired standards, but the minimum.

The idea behind competency based education is to raise the performance of all learners to the mastery level. In graphical form the ideal range of marks might look something like this:



This is certainly an improvement over the normal curve of competitive grading systems. Bloom[8] is quite convinced that this is possible in public education classrooms, and there is a large body of research to support his claims that this situation can indeed be approached.[9]

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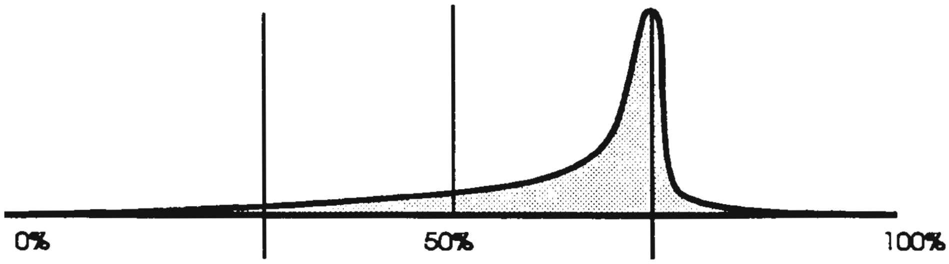
8 Bloom, *One-to-one.*

9 See Kulik, C.-L. C., Kulik, J. A., & Bangert-Drowns, R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research, 60* (2), 265-299, and Kulik, J. A., Kulik, C.-L. C., & Bangert-Drowns, R. L. (1990). Is there better evidence on mastery learning? A response to Slavin. *Review of Educational Research, 60* (2), 303-307. The Slavin article referred to here is Slavin, R. E. (1990). Mastery learning reconsidered. *Review of Educational Research, 60* (2), 300-302.

8.9 WHEN MINIMUMS BECOME MAXIMUMS

There is a problem. Instead of ending up with the situation shown in the graph on the previous page, some competency based education programs, especially under self paced computer managed learning, end up with scores that look more like this:



The reason for this is that the minimum competency level become a maximum. There is often no incentive for a learner to put in the effort to achieve more than the required minimum. This is especially true if the system has no method of certifying this achievement. If the course is part of a "pure" competency based education system, the learner is sometimes not rewarded for exceeding the minimum mastery level, and is often not given the opportunity to remediate himself beyond this level in any case. The system, especially in computer managed learning, bumps the learner to the next Chunque as soon as the minimum mastery level is achieved in a certification test.

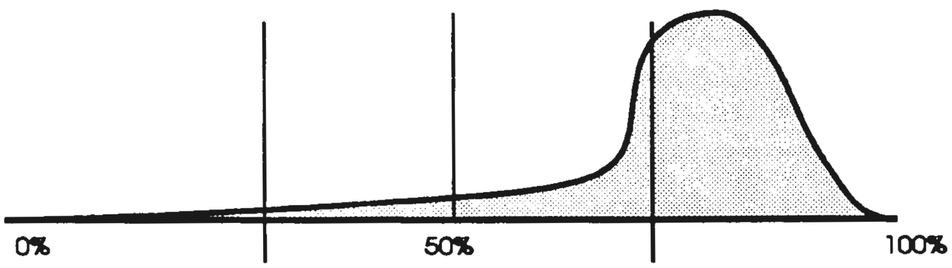
This is why such systems promote and codify mediocrity.

8.10 THE PURSUIT OF EXCELLENCE

What can the learning system designer do to encourage the learner to go beyond the minimum competency level? There must be a mechanism built into the learning system to foster and reward the pursuit of excellence. We can borrow from the competitive grading systems of the normative school to accomplish this. It is self evident that the grading system in law schools promotes and rewards the pursuit of higher grades. Not excellence, some would say, but at least higher grades.

The principles of mastery learning (which enable most learners to achieve mastery), competency based education (which measures learner performance against a fixed and known standard), and competitive grading systems (which rank learners against each other), can be combined to create an assessment system that ensures minimum competence upon certification and also provides rewards for excellence. In order to do this, the assessment system must codify excellence, and the instructional logistics system must be designed to not only allow, but encourage the student to go beyond the mastery level towards excellence. The first part of this scheme is elaborated in the next few pages, the second part in Part Nine: Micro Level Strategies.

What we are trying to do is move from the spiky graph on the last page where the minimum becomes a maximum to a situation more like this:



In this situation, there is still some variance, but most of the learners would progress beyond the minimum competence level, with a big lump of them filling the 80 to 95 range. Actually, the learners and some institutions might like this better, the learners because more of them are above mastery level, but not so far that it requires a tremendous amount of work, and the institution because the mean level is very respectable, but there are not too many 100 percenters to risk being accused of grade dilution.[10]

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10 Grade dilution is a situation where almost every learner gets a very high mark. It is a problem with credibility in many graduate schools. If everyone gets a 4.0 GPA, it becomes meaningless. You know ... "who flunked? It must be an awfully easy course."

8.11 BEYOND MINIMUM CERTIFICATION LEVELS

What can be done in an instructional logistics assessment system to promote learning beyond the minimum for certification? Let's look at a college system with a typical 4 point grading scale.

The first thing to decide is what point on the four point scale should correspond to the mastery level. For convenience, let's assume 2.0, because it is half way up the scale. This is also convenient because most of these scales permit conditional passes or some form of "non-failing" mark at the 1.5 (or so) level. If mastery is usually set at 80%, then a 2.0 would be the equivalent.[11] Any student who performed at least at the certification level (in each and every essential Chunque) would get a 2.0, and would be certified as a graduate.

Mark			80%				
Grade	1.0	1.5	2.0	2.5	3.0	3.5	4.0

A 2.0 also seems about right, as it is a *minimum* level for certification, and implies that the learner just barely made it. Not the cream of the crop by any means, but competent. Remember our airline pilot? I wouldn't want to fly with a 2.0 pilot on a rainy night with three engines out and a terrorist in the cabin. He might spill my drink. But if I owned a plane, I might loan it to him.

So what do we do with the 1.99's? Remediate them up to a 2.0. What if they choose not to do so, or are incapable of doing so? Give them a "certificate of completion" that states they completed the course and a transcript that shows a 1.99, but that they are not certified as competent. Perhaps it could be called a "certificate of incompetence."

Well, now we have defined the Chunque Theory position on minimum competency for certification. What do we do with the 2.1's to 4.0's? We use this range of grades to differentiate between the barely competent and the superlative graduate. Some specific examples will be provided later in this section.

The point to bear in mind is that the 2.0 graduate is the one you hire if there is nobody else available. The 4.0 graduates are the ones you make an offer they can't resist. And the 1.9 is the incompetent that you don't hire ... unless it's your brother-in-law.

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11 The reason for this 80% level is based on Merrill's suggestion that 80% be used as a "standard" mastery level if there are no reasons to suggest otherwise.

8.12 THE CARDINAL PRINCIPLES OF ASSESSMENT

Throughout this discussion of learning system theory I have been harping on the principle that there must be a predictable relationship between the goals and the assessment measures. This is a lead-in to the problem of melding a need for easily understandable grading systems and the underlying assumptions of mastery learning and competency based or accountable outcome oriented learning.

This is the problem in a nutshell: learning system theory prescribes that every Chunque of content has a mastery level that is dependent upon the *kinds of ideas in the Chunque*. The mastery level cannot be set based on the ability of the students. The mastery level cannot be altered to accommodate a particular learner. The mastery level cannot be the same for each Chunque, because the kinds of ideas in the Chunques are probably different.[12]

Mastery learning principles also prescribe that a student must master each Chunque before receiving certification for that Chunque. If a student cannot achieve mastery in a Chunque during the first attempt (which, in a traditional setting, is often group-based instruction in a classroom), then a formal system must be in place to provide either review or remediation.[13]

It is important in mastery learning programs to support the vision that a learner who has not achieved minimum competency in any particular Chunque has not failed. Rather, the learner requires further instruction to attain the minimum standard. It is incumbent upon the institution to provide this instruction in the from of review, remediation, or tutoring.

There are two situations regarding learner progression and mastery of minimum competence (certification). If the Chunques are a part of a prerequisite hierarchy, the learner must not be permitted to progress to the next sequential Chunque until mastery in achieved. This situation prescribes that review or remediation to achieve mastery must be accomplished immediately, or the learner is barred from continuing. The second situation concerns Chunques that do not form a part of a prerequisite hierarchy, but which have been identified as essential. In this situation, review or remediation to achieve mastery can be delayed, but the learner must achieve the minimum competency level prior to obtaining certification in the course (or program).

There is a compelling body of research which indicates that these principles are absolute. Bloom states emphatically that the single most common cause for the failure of mastery learning programs is the passing-on of learners who have not achieved mastery. If students are passed on, or if minimum competency standards are waived, the system collapses.[14]

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12 See Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

13 You will recall that review is the repetition of the same instruction (that is, repeat the course or the Chunque) while remediation is the provision of different, more elaborate instruction which provides more instructional assistance to the learner (such as self-study packages, remediation classes, or one-on-one tutoring).

14 Bloom, *One-to-one.*

8.13 LEARNING SYSTEM CERTIFICATION PRINCIPLES

To develop a learning system that incorporates these principles into a traditional system, we must find a way to implement both an easily understood and traditionally oriented "external" grading system within a mastery learning, competency based assessment system. To the outside world, the results a student can demonstrate through a transcript must represent to the external stakeholders how well the student did in a program. Employers, the public, students, and the rest of the external world must be able to see clearly where the student stands. Typically this takes the form of a credential (certificate, degree, or whatever) and a grade (grade point average, letter grade, "summa cum laude").

Pondering what this means, one can determine that the credential is a pass/fail evaluation of student accomplishment. The student got the credential or the student did not. We previously referred to this as criterion referenced or cooperative grading. On the other hand, the *grade* associated with the credential indicates whether the student is marginal or exemplary. These indicators of performance are both traditional and self-evident to the external public.

8.14 HOW ARE STUDENTS CERTIFIED FOR A DEGREE?

Let's look at how a traditional degree granting institution determines whether a student gets a degree or not. A program description specifies which courses are required to be eligible for a specific degree. Degrees are granted subject to *two* qualifications: first, the student must have successfully completed all of the required courses, and second, the student must have achieved a certain minimum grade point average across all of the courses. Sometimes there is also a minimum number of contact hours (or credits) required, but for the sake of this example, let's assume that the specification of required courses covers this.

If a student fails to complete or pass any of the specified courses, degree qualifications are incomplete. The student is not deemed to have "failed" the degree ... the student simply has not yet obtained the required standards. In this case, the student has to repeat the course (a review strategy) or write a supplemental examination (a challenge strategy) or whatever to fulfill the graduation requirements. If the student chooses not to do so, or is incapable of doing so, the student does not get a degree.

Beyond the minimum qualifications for a degree, students are ranked relative to one another by their grade point average (GPA) score. The student with a GPA of 2.0, a bare minimum for receiving a degree, is perceived by the institution, the public, and the student as a marginal graduate, but a graduate none the less.

The student with a GPA of 1.99, under the bare minimum for receiving a degree, must be perceived by the institution, the public, and the student as incompetent to hold a degree. It is incumbent upon the institution to provide some method of remediation or review to raise the learner's level of competence to the 2.0 minimum. This should be a fairly easy task for the 1.99 student, but a near impossibility for the 0.5 GPA student.

This subtle shift in emphasis is typical of the kind of revised mindset that is necessary to move from a traditional view of education to a student-centered learning system. In a learning system, the student is never "passed-on," regardless of the reasons for not achieving mastery. In a traditional system, some sort of mechanism usually exists whereby a student who has encountered intractable problems ("I broke my leg; a hurricane destroyed my house and all of my assignments") is forgiven from the requirement to demonstrate mastery. This is a disservice to the learner and a sure killer of institutional standards. The result of the forgiveness doctrine is the graduation of incompetent students.[15]

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[15] Bloom again suggests this in *One-to-one.*

8.15 LEARNING SYSTEM COURSE CERTIFICATION

Assessment in courses in a learning system follows the previous model, but incorporates the same principles at the *course* level as well as at the *program* level. Here is an exact parallel:

In order to be certified as achieving mastery in a course (an exact parallel to being granted a degree in a program), the students must attain *two* standards. First, they must pass each essential Chunque in the course (an exact parallel to passing each course in a degree program). Second, they must attain an average minimum course grade over the Chunques in the course (an exact parallel to the minimum GPA requirement for a degree).

If a student fails to complete or pass any of the specified Chunques, course qualifications are incomplete. They are not deemed to have "failed" their course ... they simply have not yet obtained the required standards. In this case, the student has to repeat the Chunque (a review strategy), or write a supplemental examination (a challenge strategy) or whatever to fulfill the course requirements. If the student chooses not to do so, or is incapable of doing so, certification is not granted in that course.

In a learning system, beyond the minimum qualifications for a course, students are ranked relative to one another by their average Chunque score. The student with a Chunque average score of 2.0, a bare minimum for passing the course, is perceived by the institution, the public, and the student as a marginal pass, but a pass none the less.

The student with a course mark of 1.99, under the bare minimum for receiving certification, must be perceived by the institution, the public, and the student as incompetent to receive credit for the course. It is incumbent on the institution to provide some method of remediation or review to raise the learner's level of competence to the 2.0 minimum. This should be a fairly easy task for the 1.99 student, but a near impossibility for the 0.5 student.

In a learning system, the student who has encountered intractable problems is granted unusual access to whatever assistance is required to gain mastery of the competencies determined to be essential. The institution will bend over backwards to provide this assistance ... but will adamantly refuse to lower standards and graduate an incompetent individual.[16]

In considering the policies used to determine certification at either the course or the program level, adherence to these essential elements of mastery learning strategies and competency based instructional principles is a critical issue. The point here is not that the Chunque Theory and instructional logistics suggest that these principles are required across the spectrum of educational institutions, but rather that, if the institution is stating that it subscribes to and delivers programs based on certifying student capabilities, these principles must be inviolate. Period.

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16 Roueche, J. E., & Baker, III, G. (1986). *Access and excellence.* Washington: American Association for Community and Junior Colleges discuss this concern at Miami-Dade community college.

8.16 AT ISSUE: COURSE GRADES

There is one interesting point regarding the second of the two standards specified on the previous pages. The requirement of attaining an overall course average (or program GPA) of 2.0 is only necessary if there is a possibility of encountering individual grades of less than 2.0 when calculating this average. In the parallel examples given here, the requirement that a learner attain a 2.0 in each course in a program or in each Chunque in a course eliminates the need for the second standard.

So why was it included, you ask? Because the traditional mentality is that there will be some "failed" courses in the program of some students, and that these failures should drag down the GPA. Learning systems theory does not support this view. There should be no penalty for trying and failing. The corollary, of course, is that there should be no credit granted for anything less than the minimum certification standard. I maintain that "failed" courses should appear on a transcript, but not be included in the calculation of GPA's. My position is similar regarding "failed" non-essential (enrichment) Chunques in courses.

Assuming that an institution or program determines that a competency based learning system is the optimal solution to the predominant educational goals, a grading system within courses must be established that provides for certification of mastery at the Chunque level.

There are six principles that must prevail:

1. Course content must be divided up into Chunques.[17]

2. The mastery level for particular Chunques will be different.[18]

3. The mastery level for any particular Chunque must be set based on the kinds of ideas in the Chunque.

4. A grade must be granted for each Chunque.

5. In order to achieve certification for a course, learners must obtain the minimum mastery level in each Chunque.

6. Standards for certification cannot be obtained by averaging of grades across Chunques. *This is imperative.*

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17 See Part Four: Partitioning the Curriculum.

18 See the last section.

8.17 SOME SAMPLES OF GRADES FOR CHUNQUES

Let's take a look at a typical implementation scheme for a learning system course. In this example, it is assumed that all of the Chunques are *essential*, and thus certification of mastery is required in *each* Chunque to obtain course credit. In this example, it is assumed that the scoring of assignments, tests, performance checklists, or whatever is recorded initially as percentage marks.[19]

These percentage marks must be converted to a standard scale which indicates performance relative to the minimum competency level. It is imperative that the same grade indicates the minimum level of acceptable performance across all Chunques, courses, and programs within a system, primarily for external validity. A pass is a pass is a pass. Different performance requirements must be addressed by establishing different relationships between test scores (or other assessment results) and the Chunque mark.

Here is an example:

Chunque One

Mark	40%	50%	60%	70%	80%	90%	95%
Grade	1.0	1.5	2.0	2.5	3.0	3.5	4.0

In this Chunque, the minimum competency level is established as 60% (for a 2.0 grade, which we previously set as an appropriate "pass"). A percentage mark below 60% indicates that the learner has not demonstrated the minimum competence required, and needs remediation in this particular Chunque to raise the mark to at least 60%. A mark of 95% indicates superlative performance: the course designers determined that 95% is indicative of perfection.[20] Marks between 60% and 95% provide a range of excellence above the minimum competency required.

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19 In the purest sense of learning system theory, it would be preferable to use some sort of grade point scheme down to the most basic level, and dispense with percentage marks altogether. While this approach is common in computer-based learning system implementations, it is difficult to sell in traditional settings.

20 This determination of the percentage mark which indicates perfection has to do with both test error and a subjective determination of what is good enough to be considered the best possible score. In most cases, this should not be 100%, except for verbatim recall assessment measures.

8.18 TWO MORE EXAMPLES

Chunque Two

Mark	60%	70%	80%	85%	90%	95%	98%
Grade	1.0	1.5	2.0	2.5	3.0	3.5	4.0

In Chunque 2, the minimum competency level has been set at 80%, which is the recommended level (by Bloom) which should normally be used if no extenuating factors dictate otherwise. The spread of marks between 85 and 98% is again used to indicate the degree of excellence beyond the basic minimum requirement.

Chunque Three

Mark	30%	40%	50%	60%	70%	80%	90%
Grade	1.0	1.5	2.0	2.5	3.0	3.5	4.0

In Chunque 3, the minimum standard has been set at 50%, which is normally not a good strategy. It indicates that the instruction is inadequate to provide support to the students to accomplish half of the things in the course. Rather than viewing this situation as "the students learned half of the content", it is more significant (relating to the likelihood of future success) to view this as "the student is incompetent in fully one half of the things I think are essential." If the course designers determined that the ideas in this Chunque should be included in the course, is it not folly to design an assessment system that states quite clearly that mastering only half of them is good enough?

A much more serious problem arises if this Chunque is part of a prerequisite sequence. In that case, there is a fair degree of certainty that the half of the competencies that were not mastered will snowball into the succeeding Chunques where it is essential that the learner have the missing competencies in order to be able to do the work required in the new Chunque. Bloom suggests that this is a guaranteed formula for failure.[21]

To determine whether a learner has demonstrated minimum competence in a range of capabilities sufficient to receive credit (certification) in a course, the student must have achieved a minimum grade of 2.0 (or whatever across-the-board standard is set) in *each* Chunque in the course. This 2.0 is an indication of a bare minimum, beneath which competence is inadequate for certification under any circumstances ... and the range of grades between 2.0 and 4.0 spans the possibilities between that bare minimum and the superlative graduate.

21 Bloom, *Human characteristics* and *One-to-one*.

8.19 ASSESSMENT MEASURES

In a Chunque-based learning system, *assessment strategies* are defined as methods used to prescribe optimal ways to evaluate student achievement. There are two types of assessment strategies. *Informative*[22] assessment strategies provide information to the student or the learning system which can be used to determine progression through a Chunque, but which are not used for student grades or certification. *Certification*[23] assessment strategies are used to determine if a learner has mastered a piece of content, and to determine when the student should progress to the next Chunque in the program. Assessment strategies address the issue of matching instructional goals and appropriate assessment measures.

Traditional Term	Learning Systems	Purpose
Formative	Informative	Not for Marks
Summative	Certification	For Marks

Assessment measures are representative examples of appropriate test items used in controlling the progress of a learner or in certifying mastery. Assessment measures can also be used to control the consistency of programs across a number of sites or institutions. By carefully specifying appropriate assessment measures for each capability in a curriculum map, the focus of the curriculum and the student performance levels required for each idea within the program may be controlled.

Assessment measures (rather than behavioral objectives) are used because there is often a lack of correspondence between objectives and test items in criterion referenced courses.[24] In many cases, curriculum designers[25] specify the objectives for a course during the initial design phase, while instructional designers, instructors, or teachers create test items after the completion of the instructional resources. This can lead to test items that are more closely related to the instructional resources than to the intent of the original objectives. By specifying at the initial design phase the assessment measures (representative kinds of test items) to be used, there is more assurance that the goals of the curriculum designers will be achieved through the completed course of studies.[26]

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22 This is the Chunque Theory term used in place of formative assessment. The term informative seems to more clearly express the intent of this type of assessment.

23 The term certification assessment is used in the Chunque Theory instead of summative assessment as it more clearly expresss the intent of this type of testing.

24 This relates to the goals and anticipated accomplishments of Section 8.2. Bloom also discusses this at length in *One-to-one*.

25 Curriculum design is concerned with what to teach; instructional design in concerned with how to teach it.

26 Additionally, performance objectives can be easily derived from the assessment measures if it is deemed necessary. David Merrill describes this process in detail in Merrill, *Component display theory*.

8.20 SPECIFICATION OF ASSESSMENT MEASURES

It is essential to maintain a predictable relationship between the requirements of an instructional goal and the characteristics of appropriate assessment measures. Different instructional goals for different types of content demand different levels of performance.[27] Assessment measures are sample criterion referenced test items used to insure that there is a predictable relationship[28] between the goals of the program and the test items that will be used to measure competence. These assessment measures do not comprise the actual tests (eg., the test banks used in computer managed learning); rather, they are representative items that have been carefully chosen to *typify* how student capabilities are to be assessed.

The techniques used to specify assessment measures for instructional programs like PASSPORT are an extension of the work of David Merrill in the Component Display Theory for intellectual skills.[29] This model proposes that performance objectives and assessment measures can be selected from a range of possibilities rather than created from scratch for each idea to be measured. The range of possibilities is created from a matrix of performance levels and types of content. While Merrill's work is directed primarily at intellectual skills, a similar technique is being developed for other types of capabilities from the Education-to-Be and Sagacity-to-Know domains.[30]

Programs to be delivered at multiple sites can also benefit from common assessment measures. By developing a carefully specified set of assessment measures for each Chunque in the curriculum map, the competency of any student can be certified regardless of the delivery site, the delivery methodology, or the particular implementation of the content. Because the criterion referenced assessment measures for each Chunque will be in place prior to the development of instructional resources, developers will have precise specifications for the subject matter necessary in each Chunque.

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27 Merrill's Component Display Theory matrix can be found in Merrill, *Component display theory*. We use this system at Lakeland College for analyzing capabilities.

28 This is derived from the work of John Keller on predictable relationships in Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum Associates.

29 See Merrill, *Component Display Theory.*

30 See the INSCITE critical incident evaluation profile in Part One.

PART NINE: MICRO-LEVEL STRATEGIES

9.1 WHAT IS MICRO-LOGISTICS?

So far, we have been talking about finding a way to personalize learning environments to accommodate students' needs and wishes primarily at the macro level. We have explored chopping a subject up into Chunques, shuffling those Chunques around to create a path or a route, and finding different ways of organizing the Chunques to promote the creation of appropriate models for the student that make the subject more teachable and more meaningful. Now it is time to look inside the Chunques to find out what makes them tick.

The micro level, within Chunques, is the arena within which the majority of instructional design theory has been developed over the last few decades. There are a great number of strategy components, models, and theories regarding the design of the transactions which make up a Chunque (micro-level design strategies), and the selection of an optimal array of these is not addressed here. The focus, instead, is on those micro-logistics strategy components that can be profitably used to guide a learner through the instruction that results from instructional design work. I believe this distinction between the design of *instruction* and the design of the associated *logistics* strategies is an important one. It provides a useful perspective on the difference between the details of the instruction itself and the critical wrap-around things that combine to make the instruction work in a broader context.

What I am proposing is this: the learning system designer can ensure that his Chunques will work if two conditions are met. The first of these is that the instruction itself is designed utilizing an appropriate mix of existing theory-based *instructional* strategy components (which are not discussed here). The second is that the Chunque includes each of the critical *micro-logistics* strategy components listed above.

The prescriptive part of learning system theory proposed here is that each of these elements must usually be incorporated into the design. The critical notion is not so much *how* this is addressed, but rather *that* it is addressed ... in a theory based way rather than an intuitive way.[1] This comes back to the earlier point that learning system theory is concerned more with the *management* of instruction than with the instruction itself, and the notion of a modular theory where each element can be altered or replaced with a more appropriate one as our current understanding of the domain grows.

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[1] This notion is based on Gropper's work in Reigeluth's *Green Book*, in Gropper, G. L. (1983b). A metatheory of instruction: a framework for analyzing and evaluating theories and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 37-53). Hillsdale, NJ: Lawrence Erlbaum Associates. Gropper stresses that analysis of the instructional situation is the heart of optimizing the design of instruction, and makes the point that it is essential that the designer address, in some fashion, a number of critical design elements.

9.2 WHAT IS A CHUNQUE?

Now let's zoom in to look inside of a Chunque to gain a more microscopic view of this element of a learning system. These seem to be the critical attributes of a Chunque:

A Chunque consists of the instruction for a collection of ideas (like facts, concepts, procedures, and principles) and their relationships which combine to form a minimal unit of understanding; a useful and substantial collection of notions.

Therefore, a Chunque is an appropriately sized unit of analysis for the design of learning systems. A Chunque is the cluster of ideas that we can use to express and address our intentions.

A Chunque is the smallest unit of content that has meaning in its own right (to the learning system designer, at least, and hopefully to both the external stakeholders and the students as well). Understanding is an internal characteristic of a Chunque. "We are always chopping complex structures into artificially clear-cut chunks, which we perceive as separate things."[2]

A Chunque is the smallest unit of content for which certification can be awarded; our Gold Star element.[3]

Micro-logistics does not so much concern itself with strategies designed for learning individual ideas in the behaviorist sense ... it deals more with recent cognitive notions of structuring all of these micro-level capabilities and uniting them into meaningful mental models.[4]

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2 Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster. (p. 232).

3 Note that these definitions apply to both primary and synthesizing Chunques.

4 See Lampert, M., & Clark, C. M. (1990). Expert knowledge and expert thinking in teaching: A response to Floden and Klinzing. *Educational Researcher, 19* (5), 21-23. Lampert and Clark suggest that "Knowing ... means actively making use of the resources that are available in the environment and being able to find them when you need them." (p. 22).

9.3 CHUNQUES VERSUS UNITS

What is the difference between a Chunque and a collection of transactions or lessons which form a unit of content in a conventional program? A Chunque consists of more than a collection of transactions to teach single ideas. A Chunque includes transactions for both the ideas themselves and for the links between the ideas. That is, synthesizers[5] (the transactions for linking knowledge) are incorporated throughout the Chunques to link the ideas into mental models. These linking transactions can assist in providing understanding.

Another fundamental distinction between units and Chunques is that the mental models which Chunques are designed to create are representations appropriate for novice learners. This notion of specially formulated representations for naive learners is an extension of the Elaboration Theory. The Elaboration Theory prescribes organizing content into hierarchies based on only one kind of relationship, derived from quite rigid logical structures. This is similar to the approach of knowledge engineers in artificial intelligence. While these knowledge structures try to capture the meaning and understanding of an expert, the resulting model is by design a complex and sophisticated structure that may not be the most appropriate model to promote learning. The underlying assumption of knowledge engineering is to capture the complexity, the subtlety, and the nuance of meanings held by the expert. Instructional systems derived from this starting point typically attempt to teach the whole thing in a manner similar to Reigeluth's analogy of a zoom lens panning the entire scene.

The underlying metaphor for the design of Chunques within a learning system is a zoom lens that moves about to capture the easiest teachable representation of the domain, to initially capture only the *essence* of the nodes and links. These nodes and links are represented in a simplified form to provide an initial easy-to-understand picture of the domain, in some respects like the advance organizers of Ausubel.[6] It might be viewed more as zooming and panning a diagram (or *depiction*) of a scene, rather than the scene itself, much as a novice medical student is provided with drawings of cells and muscles rather than photographs or the real thing. This notion of simplified initial representations is partially derived from the *media characteristics* ideas of cueing, highlighting, and so forth described by Salomon in *The interaction of Media, Cognition, and Learning.*[7]

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5 A synthesizer is one of the strategy components prescribed by the Elaboration Theory. It is a transaction designed to provide contextual links between the current notions and other notions in a curriculum. In the Chunque Theory, synthesizers are also used to reinforce within-Chunque links. See Reigeluth, C. M. (Ed.). (1983b). *Instructional-design theories and models: An overview of their current status.* Hillsdale, NJ: Lawrence Erlbaum Associates.

6 Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart, Winston.

7 Salomon, G. (1979). *The interaction of media, cognition, and learning.* San Francisco: Jossey Bass.

9.4 PHOTOS, HOLOGRAMS, AND ELABORATION

The development of Chunques specifically recognizes the value of simplified representations as initial teaching tools to provide a seed upon which to elaborate and gradually grow a more accurate and sophisticated representation of a domain. One of the benefits of this approach is that, at any point in the learning process, the student has a complete image of the domain, starting with a simplified shell of the most obvious nodes and links, and developing into a complex and intricate web of understanding. This is in many ways analogous to the difference between ordinary photographs and holograms pointed out earlier. If a portion of a photograph is cut out and examined, only a part of the original scene is visible. But this portion is visible in all of its detail. With a hologram, if a small piece is cut out, that piece still retains an image of the entire original scene, but in less detail. It is fuzzy but still comprehensive. This whole notion of emphasizing the most fundamental nodes *and* links in the initial instruction is like a hologram, aimed at providing a comprehensive but fuzzy representation for the naive learner.

The difference in the image held by a beginning student and an experienced learner is one of sophistication of the representation. In more typical instructional systems designs, the difference in representation would seem to be one of completeness, where a beginning student would hold a more accurate representation of a small part of the domain, but a more narrow perspective of the domain as a whole. The integration is left until the end; *level of integration*, then, is the variable related to duration of study. In the Chunque Theory, *complexity and sophistication* are the variables related to duration of study.

At the macro level, the Elaboration Theory[8] proposes basically the same method of attack. The primary difference is that the Elaboration Theory builds a more accurate and rigid initial structure based on only one kind of organizing content, while the Chunque Theory suggests an initial model at any level based on whatever relationships seem to make the ideas and structure more accessible to a novice learner and thus more teachable. This is a "start with something that works and fix the inconsistencies later" approach, derived from Minsky's[9] work with mental models and Riley's[10] computer interface design.

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8 Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates.

9 Minsky, *The society of mind.*

10 Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper, (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates.

9.5 EMPHASIZING WITHIN-CHUNQUE LINKS

At the micro level, it is assumed that the within-Chunque *nodes* and *links* are equally critical to understanding of the domain. It is also assumed that one of the major flaws in conventional instruction is the lack of attention given to the links, resulting in the fragmented knowledge of bits of information lacking more comprehensive understanding. At the macro level, among Chunques, it is assumed that it might be less crucial in some circumstances to know the links between Chunques. This is because the definition of a chunque is that it is comprised of a substantial piece of knowledge that has meaning in its own right. A Chunque can stand alone as a valued piece of knowledge. The whole approach to personalized instruction is based on the notion that not all learners need know all of the Chunques or their relationships. Notice, however, that the notion of personalized learning systems at the macro level includes the possibility of excluding some parts of the domain, while at the micro level, personalizing suggests changing the nature of the learning experiences to insure that every learner learns it all. I suppose one could say you can mess with the arrangement of the Chunques, but don't mess with the Chunques themselves. In this context, the holograph analogy extends to the macro level. Even with some Chunques missing from a student's repertoire, the big picture is still comprehensive, but less rich.

Another distinction between the Chunque Theory and the Elaboration Theory is that the Elaboration Theory is specifically limited to macro-level strategies, which I would call among-Chunque strategies. The semantic networks in the Chunque Theory exist on many scales at both the micro-logistics (within-Chunque) level and the macro-logistics (between-Chunque) level. The primary difference between the micro and macro level models is that micro-level Chunques *include more transactions for instruction* for both nodes (the ideas in the curriculum) and links (relationships for understanding), while macro-level paths provide primarily linking instruction (through the home base and synthesizing Chunques), as the nodes at this level are the smaller scale models developed within the Chunques.

9.6 CHUNQUES AND THE DACUM PROCESS

The DACUM people have created a sophisticated process for consensual curriculum development by practitioners within an occupation. The DACUM chart consists of a number of major bands, each comprising many boxes listing separate competencies. A competence is:

> that combination of knowledge, skills, and attitudes a person can be certified to possess, based on a set of criteria critical to the performance of a task.[11]

The notion of a chunque in many ways corresponds to one of the boxes on a DACUM chart. These boxes are defined as *tasks or competencies*: specific observable units of work.[12] Tasks are subdivided into smaller units of content called *steps*: specific elements or activities required to perform a task.

To reiterate a previous notion, the competencies or tasks in these boxes sound a lot like target objectives, which I earlier described as value-laden notions. In other words, the DACUM committee members might see these competencies as worthwhile for being successful in their jobs. These *steps* are more technical, rather than value-laden notions. These parallel enabling objectives, or the capabilities that would comprise the Chunque Theory's within-Chunque transactions.

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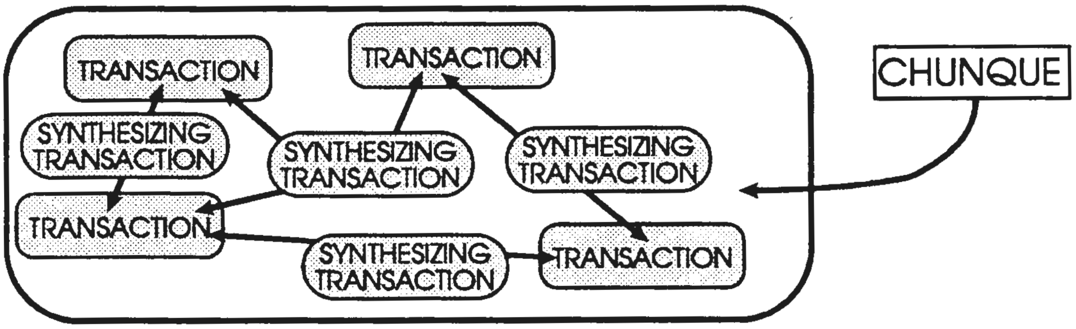
11 This is from A. Chickering, (1977). Cited in Nolan, T. D. (1990). *The DACUM process training manual*. Cincinnati, OH: Cincinnati Technical College. (pp. 1-10).

12 Nolan, *DACUM manual*, (p. 119). There is some confusion in terminology in this manual between tasks, competencies and steps.

9.7 CHUNQUES AND LINKS

Merrill's ID Expert[13] develops the idea of *transactions* as the component parts of Chunques. Each of these can be designed to provide instruction for different kinds of single ideas, much like the micro-level strategies proposed by Reigeluth.[14] This notion of transactions is an extension of the Component Display Theory[15] prescriptions for teaching facts, concepts, procedures, and principles. A number of such transactions are required to provide the instruction for each task or enabling objective. The instruction for groups of these tasks can be clustered together to form a Chunque.

A Chunque is more than a collection of transactions which are optimal for teaching each notion within the Chunque. A Chunque must include other strategy components to ensure that the student is prepared to learn the new notions, and to ensure that the student has indeed learned them at the end of the process. I believe this is a critical component of the learning process that is too often ignored in more reductionist views of instructional design. Baker[16] emphasized this point in his initial work with the design of computer managed instruction, calling, like Merrill, for a move away from a reductionist view. A Chunque must also contain transactions for synthesizing the various ideas within the Chunque, to provide our holographic view.



The required transactions for any given objective should be designed to provide a two-way dialog between the learner and the learning system whether it is a teacher based or computer based system. This provision for "conversing with the system rather than being a target for messages" is a universal goal of learning system design, and one of the characteristics that distinguish an instructional system from a learning system.[17]

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13 Merrill, M. D. (1988). An expert system for instructional design. *IEEE expert*, Summer, 25-37.

14 Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

15 Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

16 Baker, F. B. (1978). *Computer managed instruction: Theory and practice*. Englewood Cliffs, NJ: Educational Technology Publications.

17 See Draper, S. W. (1986). Display managers as the basis for user-machine communications. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 339-352). Hillsdale, NJ: Lawrence Erlbaum Associates, (pp. 347), for a discussion of this. The instructional system design perception of the learner as the receiver of messages is certainly reinforced by authors such as Fleming, M., & Levie, W. H. (1978). *Instructional message design: Principles from the behavioral sciences*. Englewood Cliffs, NJ: Educational Technology Publications, where all instruction is viewed as a series of messages transmitted by the instructional system and received by the learner.

9.8 MASTERY LEARNING AND THE CHUNQUE THEORY

Let's assume that an appropriate collection of transactions has been developed to teach the various notions within the Chunque. What instructional logistics strategies do we need to optimize the progression of a student through the transactions?

The most compelling of these strategy components form the basis of Benjamin Bloom's Learning for Mastery system (LFM)[18] and Frank Keller's Personalized System of Instruction (PSI),[19] which have been in existence since the late sixties. Either of these closely related systems will be referred to here simply as *mastery learning*.

During the last few years there has been a cat-fight of sorts regarding the validity of studies suggesting that these two systems can provide substantial improvements in student performance, led on the positive side by Kulik, Kulik, and Bangert-Drowns[20] meta-analyses spanning the history of mastery learning from 1968 until today, and on the negative side by Robert Slavin's *best-evidence* techniques.[21] Based on a number of articles in the recent literature, I side with Kulik, Kulik and Bangert-Drowns, and am convinced of the positive effects of mastery learning on student performance. The definitive work is *Effectiveness of Mastery Learning Programs: A Meta-Analysis* in the summer 1990 issue of Review of Educational Research.[22]

Mastery learning, in my view, contains a number of strategy components that I believe should form the basis of micro-logistics within Chunque-based learning systems. These strategy components are expanded over the next few pages.

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18 Bloom, B. S. (1968, May). Mastery learning. In *Evaluation comment* (Vol. 1, No. 2). Los Angeles: University of California at Los Angeles, Center for the Study of Evaluation of Instructional Programs. See also Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13 (6), 4-16; and Bloom, B. S. (Ed.). (1985). *Developing talent in young people*. New York: Ballantine.

19 Keller, F. S. (1968). "Good-bye teacher . . ." *Journal of Applied Behavioral Analysis, 1*, 79-89. See also Keller, F. S., & Sherman, J. G., (1974). *The Keller plan handbook*. Menlo Park, CA: Benjamin.

20 See Kulik, C.-L. C., Kulik, J. A., & Bangert-Drowns, R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research, 60* (2), 265-299; and Kulik, J. A., Kulik, C.-L. C., & Bangert-Drowns, R. L. (1990). Is there better evidence on mastery learning? A repose to Slavin. *Review of Educational Research, 60* (2), 303-307.

21 Slavin, R. E. (1990). Mastery learning reconsidered. *Review of Educational Research, 60* (2), 300-302.

22 Kulik, Kulik, & Bangert-Drowns, *Meta-analysis*.

9.9 FIVE CRITICAL MASTERY LEARNING VARIABLES

Kulik, Kulik, and Bangert-Drowns identify five variables across the 108 studies included in their meta-analysis that combine to produce the greatest influence on student performance.[23] These are:

1. Subject matter area. The greatest gains are in content related to the social sciences, rather than math, natural sciences, or humanities.

2. The use of locally developed tests rather than standardized commercial tests.

3. Teacher paced rather than student paced instruction.

4. High mastery levels demanded for informative assessment.

5. The use of more quiz feedback (informative evaluation).

The meta-analysis also found evidence to support the proposition that mastery learning strategies provided more gain in performance for lower ability students, thus tending to reduce the variance in performance across ability levels.

The overall effect size averaged 0.52 standard deviations. That means that the average student in a mastery learning program performed at the seventieth percentile, a twenty point rise in accomplishment. It would seem that the inclusion of mastery learning strategies within a learning system would be a wise choice.

Looking at these five critical variables, it would appear that we can opt to use four of the five in practically any learning system. The only one of these five that is a condition or a given is the subject matter area. We do not have much choice in selecting the subject matter: that is up to the stakeholders. However, it should be noted that these strategies might be more effective in the social sciences.

Even though we don't have much control over the content itself, we do have control over how it is presented. We can transform the subject matter to aid in understanding and teachability ... to encourage the construction and use of appropriate mental representations.[24]

These strategy components illustrate the crossover between instructional design and instructional logistics. These might well be classified as instructional design strategies rather than micro-logistic strategies, but their significance in designing more effective learning systems can be in little doubt.

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23 Kulik, Kulik, & Bangert-Drowns, *Meta-analysis.*

24 Brown, J. S. (1986). From cognitive to social ergonomics and beyond. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 457-486). Hillsdale, NJ: Lawrence Erlbaum Associates. (p. 465).

9.10 MICRO-LOGISTICS AND LEARNING FOR MASTERY

Well then, just what are the instructional strategies drawn from LFM and PSI that can be incorporated into our learning system proposals? There seem to be seven propositions based on the findings above and on mastery learning theory:

1. Students will perform better if they have the required prerequisite knowledge and skills at the beginning of a Chunque.[25]

2. The amount of instructional time provided for learning (the pacing of instruction) varies depending on the need of the learner,[26] and is controlled by the teacher (or system).[27]

3. Informative assessment and meaningful feedback is provided throughout the learning experiences.

4. High mastery levels on informative assessment are demanded.[28]

5. Remediation is provided to correct misconceptions.[29]

6. Progression to the next Chunque is dependent upon certification of mastery in the current Chunque.[30]

7. Locally developed assessment measures, keyed to the objectives of the Chunque, are used for certification.[31]

As I pointed out earlier, the focus of this book is on the management strategies that can be used to develop the instructional logistics portion of a learning system. I believe that the seven primary *instructional* strategies listed here can be used in combination to increase the effectiveness of within-Chunque instruction. However, a detailed look at each of these is beyond the scope of this work.

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25 Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill.

26 Bloom, *Human characteristics*, and Kulik, Kulik, & Bangert-Drowns, *Meta-analysis*.

27 Kulik, Kulik, & Bangert-Drowns, *Meta-analysis*.

28 Kulik, Kulik, & Bangert-Drowns, *Meta-analysis*.

29 Bloom, *Human characteristics*.

30 Bloom, *Human characteristics*.

31 Kulik, Kulik, & Bangert-Drowns, *Meta-analysis*.

9.11 CHUNQUE SPECIFICATIONS

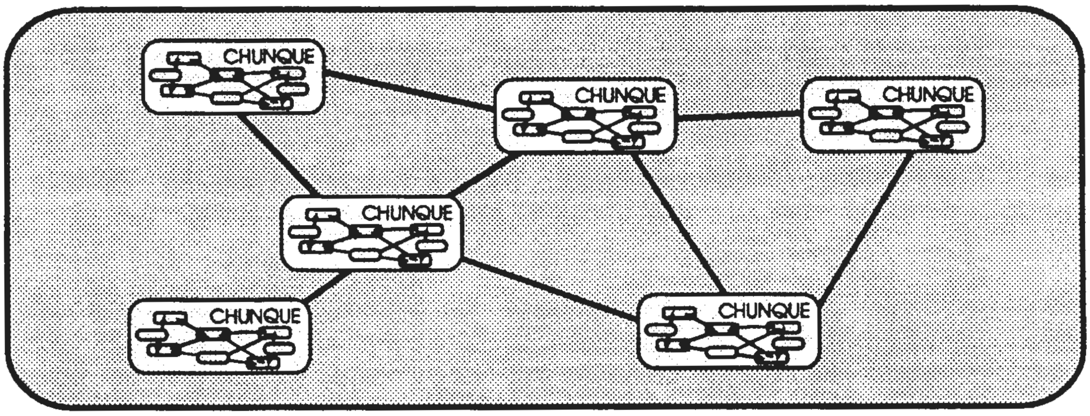
The micro-level instructional strategy components on the previous pages, derived from mastery learning, provide the basis of within-Chunque instruction. In addition, however, there are a number of other critical aspects of a Chunque that are required in order to make a Chunque *work* within a modularized learning system. Here are some other characteristics of a Chunque that ensure that it will function in a useful way within a learning system. These qualities form the cardinal principles of Chunque design which are the foundation of this section:

A Chunque must be *self contained.* That is, it must comprise a stand alone piece of instruction (or collection of instructional resources) for all of the transactions that are required, and that can be delivered in isolation from other Chunques, if necessary.

A Chunque must have *embedded entry and exit assessment* of student capabilities, the entry assessment to ensure adequate prerequisite skills, and the exit assessment to define just what set of competencies and their appropriate mastery levels are included in the Chunque.

A Chunque must provide embedded systems for *review, remediation, and one-on-one tutoring* that are anchored to each competency.

A Chunque must result in understanding of a *cluster of related ideas*. A Chunque is only expected to provide this internal understanding of the content ideas, however. It is the function of the macro-level elements of the learning system to provide contextual meaning for the isolated understandings developed by each individual Chunque. The system, through the home base, must provide *hooks* to other Chunques.



This set of essential characteristics provides a snapshot of what a Chunque should be like. If each of these elements is incorporated into the design of each Chunque in a learning system, it should ensure that the ideas in the curriculum are presented in a more teachable form. I believe these cardinal elements are *all* essential in order for a learning system to work effectively.

9.12 SELF CONTAINED CHUNQUES

Chunques must be self contained pieces of instruction because they must function in isolation from other Chunques. The whole idea of Chunque-based learning systems is to mix and match from a collection of Chunques to build an optimal path. This will work only if each Chunque can stand alone.

This does not imply that there are no prerequisites or other things that reside outside the Chunque, only that the Chunque is a complete package to achieve mastery of the included capabilities. The Chunque specifications must state clearly what content is included within the Chunque to delimit the boundaries of the particular Chunque. The entry and exit capabilities must be carefully specified for each Chunque so that the necessary prerequisite Chunques for any given Chunque can be identified. The exit capabilities for one Chunque might comprise some or all of the entry capabilities required for another. These specifications ensure that all of the Chunques can fit together in a multitude of different ways, and ensure that no required capabilities fall between the cracks.

Each Chunque also has to contain within itself the other logistics and instructional components discussed in the next few sections. The bottom line is that each Chunque must become a sort of small micro-world of ideas and relationships.

Within the Chunque there is an opportunity to look at the precision design of instruction that is the goal of much micro level instructional design. Coupled with this, however, is a constraint on flexibility compared to the macro level. The student must end up with a high level of mastery of the notions within the Chunque, because the other Chunques are designed under the assumption that entering students have achieved mastery of the previous Chunques in the path.

Mastery learning provides a powerful collection of strategy components that can be used to achieve this. Mastery learning in this context consists mainly of logistics strategies which prescribe the management of the learning experiences rather than instructional strategies.

9.13 ASSESSING ENTRY CAPABILITIES

Entry level assessment of prerequisite capabilities is recognized in mastery learning as one of the essential elements of a successful program. Bloom suggests that, while a combination of a number of crucial elements provides the most powerful learning environment, whether the student possesses necessary prerequisites is one of the most critical of these.[32] If a student enters a Chunque without having the necessary prerequisite capabilities, then upgrading must be provided somewhere within the path.[33] Of course, if proper assessment of mastery has been done in the preceding Chunques, this situation will not arise. This points out the critical nature of assessing mastery at the exit of each Chunque.

Because entry capabilities are such a critical determinant of success, it is the responsibility of a learning system designer to ensure that they are assessed in each Chunque. This requires entry testing of some sort that is keyed to specific prerequisites for the content in the Chunque. Note that, even if we are dealing with a totally linear path comprised of sequential Chunques, there is a difference between the exit certification of one Chunque and the entry prerequisites of the next. It is highly unlikely that *every* capability included in the first Chunque is a required prerequisite for the next. Which of these capabilities, plus any others, that are prerequisites must be determined during the design of the Chunque, and assessment of each must be included in the entry level testing.

The curriculum, as developed and clustered into Chunques, defines the total array of capabilities that are required of a graduate. It is fair to assume that very few students will need to learn every capability: they all come in with some knowledge or capabilities. Just as it is crucial to include exit assessment and to remediate to ensure that the student has all of the capabilities when leaving a program, it is important to discover what capabilities the student has when entering, and to customize the learning experiences so that the student is not required to re-take things that are already known. At first, it would seem that this is primarily a matter of efficiency, but being compelled to study again things that are already known can certainly affect motivation as well. It is well recognized that some of the more capable learners are bored with the pace of instruction, and with the drudgery of enduring unnecessary re-learning. This again is an example of the benefits deriving from customizing the learning experiences for each individual.

Another important distinction to make is between assessment of necessary prerequisites, which addresses what must be known before attacking the Chunque, and challenge exams, which determine if a student possesses any of the capabilities addressed within the Chunque, which are exit requirements. The first of these determines whether the student needs assistance in order to gain the required prerequisite capabilities to learn the new material, the second whether the student can legitimately be excused from taking parts of the Chunque because the notions have previously been mastered. This second part is an example of the TOWTDAK principle from Part Six. These two kinds of entry assessment must not be confused.

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32 Bloom, *Human characteristics*, and Bloom, *One-to-one*.

9.14 INFORMATIVE TESTING

While the ideas in the previous section pertain to assessment prior to entering a Chunque, the whole area of within-Chunque assessment has yet to be explored. This within-Chunque assessment must be designed in a way that is non-threatening to the student so that it is viewed as assistance in learning rather than a contest between the student and the system. I call this internal assessment *informative*, rather than the more common term *formative* testing, which derives more from program evaluation than from student assessment. Informative testing is designed to provide feedback to the student (and the system) regarding the mastery of particular notions. It must not be used for marks or grades.

Informative assessment is also diagnostic, in the sense that it should be designed to identify particular misconceptions. As an example, I understand that there are some eleven different misconceptions that a student can have regarding the multiplication of multiple digit numbers. The informative assessment provided through practice items should be designed to key on each of these possible errors and identify which, if any, a particular student is making which result in incorrect answers. In this way, the informative items can be linked to specific remediation to correct the misconceptions.

Of course, this would quickly become an overwhelming project if all possible misconceptions across all of the notions in the many Chunques comprising a learning system were to be addressed. But, if the essential principle of this approach was recognized, an incremental movement towards this goal, beginning with the most common or most intractable misconceptions, would provide valuable assistance to the learners. Once again, it is a question of mind frame.

The issue here is the recognition of a method of attack. Informative testing can identify particular difficulties and prescribe remediation to address these difficulties. This is a substantially different approach than presenting a large body of new content and ideas, and then testing across the totality of this in a right/wrong fashion to provide a non-specific percentage grade. What information does a 43% mark in a math exam really provide that is going to facilitate improvement in student performance? I maintain that if a student can be convinced that informative assessment will be used as a tool to improve performance and ease the burden of learning, tests will be welcomed as an aid rather than a punishment. If we can couple this with effective and timely remediation, we will once again have moved from content centered to student centered learning systems.

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[33] This will be addressed in a later section on remediation strategies.

9.15 CERTIFICATION TESTING

At the tail end of any primary-level Chunque, exit assessment provides a degree of certainty that the student has mastered the capabilities in the Chunque and provides the data required to grant certification. Somewhere assessment must be provided that determines both mastery of individual capabilities within the Chunque and mastery of the more general or global notions that make up the understanding of the notions in the Chunque. Remember that a Chunque is defined as a useful and substantial collection of notions that has some independent existence. Too often, exit assessment becomes focussed on reductionist objectives while ignoring the overall picture; it addresses the nodes, and ignores the links.

The old programmed learning systems generally assessed each idea in the most minute sense, at the end of each frame, but through this lost the larger picture which learning system theory suggests aids in understanding. It would seem that certification of mastery of individual capabilities (the nodes) might be embedded throughout the transactions in the Chunque, and may not have to be addressed at the end, but the more global synthesis of these nodes must probably occur near the end.

Riley[34] suggests that coherence and validity are internal aspects of the notions within a Chunque, and therefore must be assessed within each Chunque. This is similar to what I am calling *understanding*. Integration with other Chunques (*meaning*) is more of an external requirement, which must be addressed elsewhere within a particular path. This becomes one of the functions of a home base.

A powerful motivational idea is to ensure that student are not confronted with an exit certification exam until they are assured of passing it. By this, I am suggesting that the informative testing provided within a Chunque should provide the student with enough prior information on performance during the course of the instruction that when all of the transactions have been completed, the student will be confident of passing the certification test.

Back in Part Eight, when addressing assessment and the pursuit of excellence, I brought up the point of codifying a way to encourage the student to move beyond minimum competence to strive for excellence. The exit assessment for mastery must address this issue. In some prominent computer managed learning systems, the exit certification tests automatically kick the student out of the Chunque as soon as the magic minimum standard is met. We must be careful that we do not design our certification tests in this manner.

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[34] Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates. This is explored more fully in Part Ten.

9.16 REPAIRING MISCONCEPTIONS

The learning system designer has to have a different mind-frame regarding the handling of student errors and misconceptions than is typically encountered in instructional design. A learning system must be designed not for the avoidance of trouble, but for the management of trouble. The learning system designer must expect and treat misconceptions, slips, and mistakes as the norm. Having strategies in place to repair error is a crucial proposition.[35] We tend to focus on developing perfect initial instruction, and deal with shortcomings as an afterthought, occasionally going so far as Engelmann and Carnine, who propose that in correctly designed instructional systems the fault always lies with the imperfect learner.

Learners are seldom perfect, and instruction never is.[36] Errors and misconceptions are always going to be present, and can arise from a variety of sources. Perhaps the student missed the lesson, and never did learn. Perhaps the student forgot, or perhaps the student knew perfectly well, except what was known was wrong. The learning systems designer is faced with all of these gaps and misconceptions, and must provide strategies to overcome or correct them. The next few pages provide a tentative taxonomy of shortcomings and a discussion of various review, remediation, and tutoring strategies that can be utilized to overcome them.

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35 Brown, *Cognitive ergonomics,* (p. 465).

36 You might note that this is exactly the opposite position to that taken by Engelmann and Carnine mentioned earlier. In Engelmann, S., & Carnine, D. (1982). *Theory of instruction: Principles and applications.* New York: Irvington, they suggest that the goal in instructional design is to create perfect instruction: then any failure to learn is due to a faulty learner.

9.17 A TENTATIVE TAXONOMY OF TROUBLES

This section provides a taxonomy of kinds of troubles. What kinds of errors, gaps, misconceptions, mistakes and slips occur in the process of learning ? What do these notions mean, and where do they come from? How do we deal with them? Each might have to be dealt with differently. We have not considered this much in the design of instruction.[37]

This taxonomy of troubles is tentative because much work remains to be done in our field to explore the causes and conditions of trouble in learning land and to prescribe optimal strategies to overcome the shortfall. There can be little doubt that, to make learning systems effective, some provision must be made for corrective assistance that is both *formalized* and *mandatory*. If we are to propose, as Banathy suggests,[38] that the student is primary in the design of student-centered learning systems, we are obliged to provide this assistance as an integral part of the system. It is no longer adequate to use what Merrill describes as the "Spray and Pray" mindframe, where instruction is *presented* and learning is seen as the responsibility of the learner.

How can errors or shortfalls be classified? One way might be to determine if the student is aware of the problem. Does the student know there is something wrong? In some cases, the student will think everything is okay until the test is returned, in other cases the learner will know something didn't work quite right.

If the student knows something is amiss, the problem can be classified into one of at least three categories. I have been known on occasion to flick my cigarette ashes into my coffee cup. In rare instances I have then drank the coffee. It is fair to assume that I know this is not an intentional action. Norman, in POET,[39] calls this a *slip*, an error where one is perfectly aware of the intention and the required action, but inadvertently performs a different and incorrect action. A slip.

It is also possible to know that something is wrong, but to be incapable of doing anything in the sense that the solution is unknown. This was a common occurrence in my previous life as an engineering student, especially in calculus. I was incapable of performing the necessary calculations for many problems, and knew it. I call this being *incapable.*

Another situation might be where a student lacks the necessary skill, primarily a motor skill, as in learning to play tennis where faulty form causes problems. The player knows in a cognitive sense how to do it right, but requires more practice to optimize the performance. This is a problem in *lacking skill.*

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37 Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books.

38 Banathy, B. H. (1987). Instructional Systems Design. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 85-112). Hillsdale, NJ Lawrence Erlbaum Associates.

39 Norman, *Everyday things.*

9.18 IGNORANCE IS BLISS

Another major class of errors occurs where the student is unaware of a problem. Everything appears to be fine until the test comes back (if there ever is one). There are two different situations where this kind of error can occur. In one case, the student has the right goal, but the wrong solution. Norman suggests that this results from the application of an incorrect or inappropriate mental model of the situation. I call it a *misconception.* But there is also the reverse situation, where it is the goal that is wrong, but the model is correct. Norman provides a dramatic example from an airline incident in Florida.[40] In this case the pilots received information that the oil pressure in all three engines was gone. They decided that the problem was with the instruments, and set the goals of restarting the engines, continuing to their destination, and not alarming the passengers. The oil pressure was in fact zero, as all three engines had the same washer left out of the drain plug. They made it. This is an example of a *mistake.*

Another aspect of the error correction problem concerns *when* the error is encountered. If the student is lacking in prerequisite entry capabilities, the required corrective action is termed *upgrading.* Upgrading provides missing capabilities that have been defined or specified as required entry level competencies, and should be uncovered by diagnostic entry assessment. If the student encounters difficulties during the instruction within a Chunque, the required corrective action is called *remediation,* defined here as additional learning experiences to overcome shortcomings in within-Chunque capabilities. Remediation should be provided within the Chunque. Upgrading is another matter. If the student lacks prerequisite entry capabilities, it is difficult to provide them within the new Chunque: the shortcoming should have been overcome in the previous Chunques where the ideas were initially taught. This points out again the critical problems that arise if students are passed out of a Chunque without achieving mastery.

There is a semantics problem which will be encountered shortly, where the term *remediation* is used in two different senses. I could solve this problem by inventing another new term. I would prefer Bob Newhart's *gzornenplatt,* but reason prevails.[41]

You will recall that the mastery learning research cited earlier in this section supported the proposition that high mastery levels be demanded in informative assessment. If we are to accomplish this, we need to have robust remediation systems in place to overcome student shortfalls. This is an essential element of success. No more Spray and Pray, thank you.

Even though this taxonomy is very tentative and certainly speculative, it would seem that different kinds of errors would require different correctional strategies.[42] Much more work remains to be done in this area.

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40 Norman, *Everyday things.*

41 This is from a long forgotten Bob Newhart monologue where he is monitoring an infinite number on monkeys sitting at typewriters testing the hypothesis that they will eventually type all of the great books. One types "To be or not to be ... that is the gzornenplatt." Oh well.

42 This might actually be more properly called a *typology.*

9.19 REMEDIATION STRATEGIES

I have suggested that it is the responsibility of learning system designers to build formal and mandatory remediation strategies into the system. I believe they must be formalized so they are viewed as an integral part of the learning experiences which make up a student's path through the Chunques. I believe they must be mandatory based on the proposition that learners tend to select inappropriate amounts of instruction if given the opportunity.[43] The remediation strategies proposed here fall into three categories: *review*, which means "do it again", *remediation* (in the second sense), which means "do it differently", and *one-on-one tutoring*, which implies doing it interactively with a live tutor.[44]

I see these three levels as increasing in power to overcome errors. At the lowest level, review simply provides another opportunity to learn. The problem might be that if the student did not understand it the first time, why would he expect understanding the second time? This only applies if the student actually tried to understand during the first encounter, not if the student was not there or was not attending to the instruction.[45] This review strategy is not very powerful. It might be more valuable to improve retention rather than to provide another opportunity for initial learning.

Remediation demands that the same notions be presented in a different fashion. Merrill would call this a *secondary presentation strategy*.[46] The difference could be in the analogy, in the treatment metaphor, in the examples used, or in the instructor. The essential element of gzor ... excuse me, ... *remediation* is that the transactions present the ideas from a different perspective to provide the opportunity for a student to learn in a different way. This is certainly a more powerful strategy than review, but it takes a lot more work. My old friend Don Manuel suggests that we save the most powerful strategies for the most intractable *instructional* problems.[47] Not learning problems, but instructional problems. If review doesn't work, try remediation. If that fails, try one-on-one tutoring. If that fails, give up.

By one-on-one tutoring, I am proposing that, if all else fails, every learning system, whether it be the most tradition-oriented classroom program or the most sophisticated intelligent interactive video system, should always provide a remediation system that drops through to a real live mentor. Somewhere there should be a phone number or posted office hours or something, so, as a last resort, the student can find a warm live body. If all else fails, I suggest that it be you, the designer. Go ahead. Stick your phone number on the help screens.

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43 Ross, S. M., & Morrison, G. R. (1989). In search of a happy medium in instructional technology research: Issues concerning external validity, media replications, and learner control. *Educational Technology Research and Development, 37* (1), 19-33.

44 I suppose this could also imply doing it interactively with an intelligent computer tutoring system, but I think it might, in general, be better to have this drop through to a real person.

45 This might be an example of what Engelmann and Camine mean by perfect instruction and faulty students. See *Theory of instruction.*

46 See Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279-333). Hillsdale, NJ: Lawrence Erlbaum Associates.

47 Don Manuel runs a turnkey industrial training operation in Edmonton, Alberta, *The Training Group.*

9.20 MASTERY LEVELS AND THE SNOWBALL EFFECT

There would seem to be a critical mass of entry level competencies for any given Chunque. This minimal body of entry competencies is the basis for selecting a mastery level for each Chunque. Merrill suggests, in the Component Display Theory,[48] that there are different mastery levels for different classes of ideas. While mastery is commonly set at 80%, this figure is arbitrary, and dependent on the kinds of ideas in the Chunque. For instance, when learning the multiplication table, what would be an appropriate mastery level? How would a learning system designer determine an appropriate level?

Merrill would say it depends on the kind of idea, and the level of performance required. In the multiplication table, for example, the kind of ideas are facts. Four times seven is twenty eight. This (in this particular case) is a fact rather than a solution to a problem solving sequence, because we want the learner to recall the answer to four times seven without figuring it out. The point in learning the multiplication table is to have the learner be able to recall the answer as a computational tool used in more complex mathematical operations. If the learner had to figure out each single digit multiplication answer every time it was needed, it would take forever to do a long division. In computer design, this is called a *look up table*. It is more efficient for a computer to look up the simple answers rather than calculate them each time. Similarly, in the case of a learner remembering the multiplication table, it is a matter of efficiency to recall any of the 144 answers (facts) when needed. Therefore, the level of performance is to recall the facts. In this case, the mastery level should be set at 100%. Remembering eighty percent of the multiplication table is not a sufficient body of knowledge to easily master the more difficult procedures, multiple digit multiplication or long division. A twenty percent deficiency will hamper the learner to an extent that difficulty could be encountered in the next Chunques in the sequence (multiplication or division). It is unlikely that a learner could solve the necessary problems by figuring out the multiplication table answers for twenty percent of the cases, and, realistically, somewhat questionable whether a learner who accomplished less that eighty percent would have the skills to calculate the answers in any case. Now, what do you suppose the result is when a learner passes a typical normative based unit with a fifty percent mark, and cannot recall one out of two necessary answers?

Bloom[49] suggests that snowballing failure is the inevitable outcome. This serves as one example of the setting of mastery levels. For the recall fact content-performance level, 100% is appropriate. For higher levels of content-performance outcomes, Merrill suggests progressively lower mastery levels, as the outcomes become less concrete.

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48 Merrill, *Component display theory*.

49 Bloom, *One-to-one*.

9.21 TIMING REMEDIATION STRATEGIES

Whatever prerequisite shortfall exists for a particular student at any particular time must be remediated prior to the presentation of any new content for which that capability is required. The choice as to whether to provide upgrading for all lacking prerequisites at the beginning of the Chunque or at a later time is still an open question. In a similar fashion, within Chunque remediation can also be provided immediately when the shortfall is discovered, or just before it is needed as a prerequisite. It is essential that the shortfall be overcome before new content which depends on it is encountered. Recent work by Reigeluth[50] and Keller[51] suggest that prerequisite knowledge be provided just prior to the new learning, for both instructional and motivational reasons. Reigeluth proposes that providing prerequisite knowledge just before it is required will link it more readily to the new notions, while Keller suggests that it will be more appealing to students at that time because it will be relevant to the newly encountered content.

In a practical sense, spaced upgrading or remediation also eases the burden on both the student and the learning system in scheduling and in the amount of extra effort required to learn the required prerequisites. This again is an area where sophisticated CML systems can provide logistic assistance to both the student and the teacher by tracking the shortfalls and scheduling remediation to occur just before it is required.

It is important to differentiate between situations where the student needs the capability *right now* or at the point of certification. Prerequisite strategies would prescribe that all notions be structured into a prerequisite hierarchy which began at the most elemental level and gradually worked up to more general ideas. These would tend to provide all prerequisites in a cumulation mode. The Elaboration Theory suggests that prerequisite knowledge be provided just when it is needed, as a motivational strategy, as the prerequisite knowledge would be relevant and required. I believe that required prerequisite knowledge should be provided at the point where it will link most easily into existing student models. As long as it is available to the student at some point before it is needed, why not pick the spot where it fits in the best?

One final point: you cannot have a remediation path. Remediation cannot be anticipatory, it must be adaptive, based on hard data about student performance and misconceptions.

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50 Reigeluth, *Elaboration theory.*

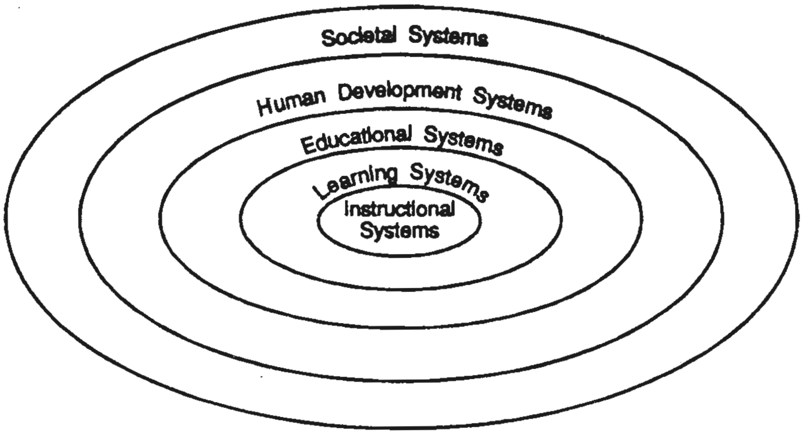
51 Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum Associates. Keller also discussed this at the Canadian Centre for Learning Systems symposia series, November 17, 1988.

PART TEN: MNETS

10.1 A WHOLE NEW WAY OF LOOKING AT THINGS

I believe that the way we represent things fundamentally affects our understanding of them and the meanings we place on them. Here is a bizarre example.

Just after I thought I had finished this work, I ended up on the Monterey peninsula at a NATO workshop on educational reform and the possibility that systems theory might provide a valuable set of tools for implementing reform.[1] The systems theorists kept talking about boundaries, systems, and environments. They also talked a lot about figure/ground relationships and how no systems existed in nature ... that they are all convenient inventions of man to explain our reality. This bent my brain for a few days.



The diagram in Part One (our *Bermuda Onion Model* of educational systems) was developed at this workshop. I was troubled because this diagram set instructional design in the center as a very small circle, with "societal systems" as the outer circle. What would happen if the circles were reversed, with societal systems in the middle and instructional systems on the outside? This might provide an entirely different perspective on the reality of systems of education. When I discussed this dilemma with the systems people, they suggested that it didn't matter, it was a figure/ground problem that resided in the diagram, not the ideas it represented.

Systems people might be able to think in these terms, but I certainly could not. Then, about four am in my hotel room the night before my defense, it struck me: the problem was that I was drawing the diagram on a two-dimensional piece of paper. What if I drew it on a sphere? ... on a baseball, for instance?

The next morning, my wife, who by this point was beginning once again to question my sanity, was out looking for baseballs and a package of rubber bands.

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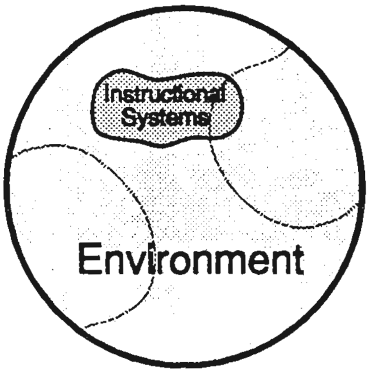
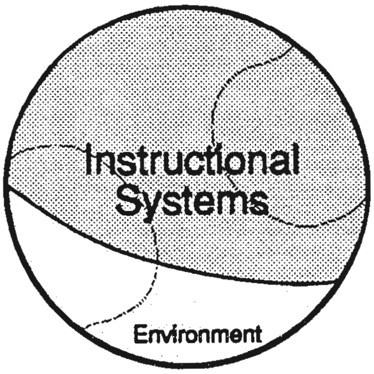
[1] This was a workshop organized by Charles Reigeluth and Bela Banathy, sponsored by the North Atlantic Treaty Organization and held at the Asilomar Conference Centre in Monterey, California in December of 1990. It brought together about thirty five systems theorists and educational technologists from the NATO countries.

10.2 BASEBALLS AND RUBBER BANDS

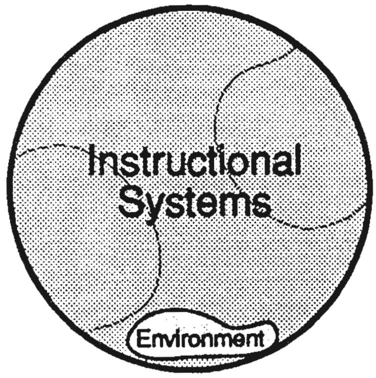
Let's look at only one part of the *Bermuda Onion Model* ... say the instructional systems part. If we stick a small rubber band on the baseball to represent the system of "instructional systems", the band encircles a small portion of the surface of the ball which represents the "instructional systems" space. The rest of the ball's surface represents the environment within which the instructional systems space resides.



But what has this to do with figure/ground? Well, if you push the rubber band so that it fits around the middle of the ball, the system constrained by the band and the environment around it become the same size:

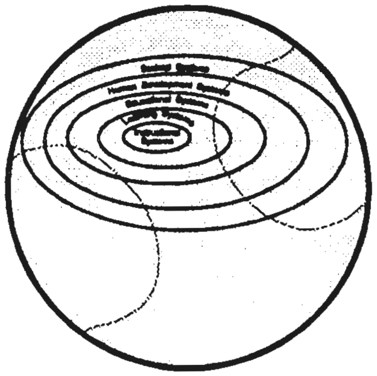


If you push the band even farther, around toward the other side of the ball, the system space becomes larger than the environment space.



10.3 SYSTEMS SPACE AND ENVIRONMENTS

If we look at a ball where the rubber band for the system has been pushed around until it is much larger in size than the environment, our perception might shift. The little part, the environment, would probably look to that person like the part of interest, and the big part, the instructional system, might look like the "environment." It would seem that the representation on a sphere could provide a whole new way of looking at things. So I imagined putting the Bermuda Onion Model of concentric circles on my baseballs, and suddenly it did not matter whether the instructional systems space was in the middle or on the outside. I just had to push the rubber bands to an appropriate place of the baseball, and I could alter the perception of the relationships among the systems in the Bermuda Onion.



Then I thought about the seams on the baseball, so I painted one part red. Now I had a figure/ground, or system/environment set represented by the two pieces of weird shaped leather which cover the ball.

So what is the point? What would happen if I tried to represent a cluster of clouds from our curriculum development model on a baseball? Or the relational network representing Learning Systems as presented in this book in Part One?

Well, I am convinced that the way we represent our knowledge domains or systems, especially when constrained to two-dimensional pieces of paper or curved surfaces on baseballs, can have a crucial impact on our meaning and understanding. What if we could conceive of these systems in a multi-dimensional space? My statistics professor once explained factor analysis with the metaphor of a bunch of ping-pong balls suspended in three dimensional space. All we had to do was determine the plane that was closest to all of them.

This section has to do with representing knowledge in a manner that makes it easy for a novice learner to understand. It is a preliminary investigation of how we might use three notions to make things more learnable: the notion of mental models, as proposed by Minsky in *The Society of Mind*, the notion of user interface design for computers expressed by the various authors in Norman and Draper's *User Centered Systems Design,* and some very tentative notions about baseballs, rubber bands, and systems theory.

10.4 MENTAL MODELS: A COMPUTER PARADIGM

I believe that we should use notions about mental models as a basis for designing learning systems. As Minsky and Norman point out, as far as we can tell, people do construct mental models to explain new things. Students are going to construct mental models whether we intentionally build them into our instruction or not. As Norman suggests,

> We base our mental models on whatever knowledge we have, real or imaginary, naive or sophisticated. Mental models are often constructed from fragmentary evidence, with but a poor understanding of what is happening, and with a kind of naive psychology that postulates causes, mechanisms, and relationships even when there are none.[2]

In order to explore the relationships among the representations of reality held by the many partners in a knowledge domain, I would like to examine the micro-world of computer designers and users. In their book *User Centered System Design*, Norman and Draper[3] discuss the relationships among a number of different mental models held by the participants in the design and use of computer systems and interfaces.

Norman calls the model of a computer system held by the designer the *design model*, which is the designer's cognitive representation of the *prototyp*[4] system, the designer's internal image of what the system he or she is creating is supposed to be and supposed to do. The mental model of the system formed by the end user is called the *user's model*. As we will see shortly, these two models interact, but often do not coincide.

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2 Norman, D. A. (1988). *The psychology of everyday things*. New York: Basic Books. (p. 38).

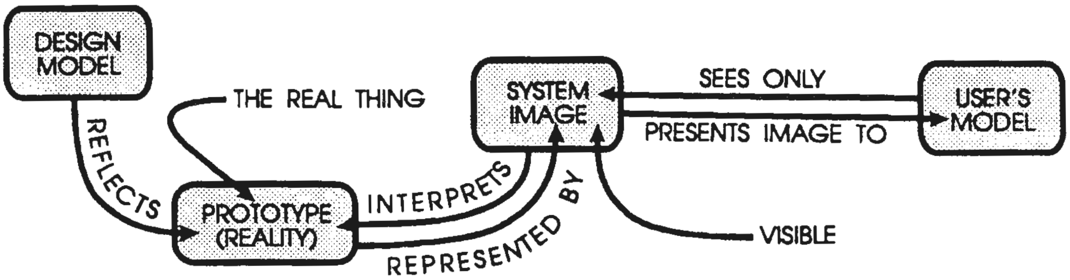
3 Norman, D. A., & Draper, S. W. (Eds.). (1986). *User centered systems design: New perspectives on human-computer interaction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

4 I have called the physical reality of a domain the *prototype*. This is a slightly different usage of the term than in some current literature. Some writers, notably Norman, use prototype to denote a *conceptual* construct similar to Plato's forms: a default template of the archetypical notion. Designers often use the term to describe the first example of a product, a preproduction *object*. One can see that these usages alternate between the physical world and the mental representation. In this paper, *prototype* refers to the physical reality which is the source of a mental model.

10.5 A SYSTEM IMAGE

Another representation that links the design model with the user's model is the *system image*. The system image is the representation of the prototype that is provided by the actual computer system as, for instance, a word processing package and its interface, manuals, and help screens. It is the visible part of a device.[5]

A gap exists between the design model and the end user. The user does not really have access to the prototype. The user cannot usually see into the actual program, but only the impression of the program represented through the user interface as a system image. This adds another iteration into the cycles of interpretation that stand between the designer and the user. The system image interprets the prototype for the user. Note that at first look, the system image could be assumed to be an accurate representation of the physical prototype (the hardware and software), but that is not necessarily the case.



The system image is what the computer interface presents to the user; it is what the user *thinks* the prototype is, based on the user interface and how the program *appears* to work. The system image can, and often does, give a false picture of how the program actually functions. In the computer paradigm, the system image mediates between the prototype and the user's model. The acquisition of an appropriate user's model depends on the system image. Note also that the gap between the prototype and the design model can usually be assumed to be very small: the program that results from the design efforts will be a close match, except for program bugs.

A significant point is that the user's model is not a reflection of either the design model (what the designer intended) or the prototype (what actually exists), but of the system image (what the system interface presents to the user). Under typical circumstances, the user does not have access to the designer (and thus the design model), but only the product of his design. Even though the user does have access to the prototype, it is often so complex and opaque in its complexity that it cannot be understood without a great deal of exploration and experience. For these reasons, the user's understanding of the system, initially at least, derives from the system image it presents. Is there a parallel in education?

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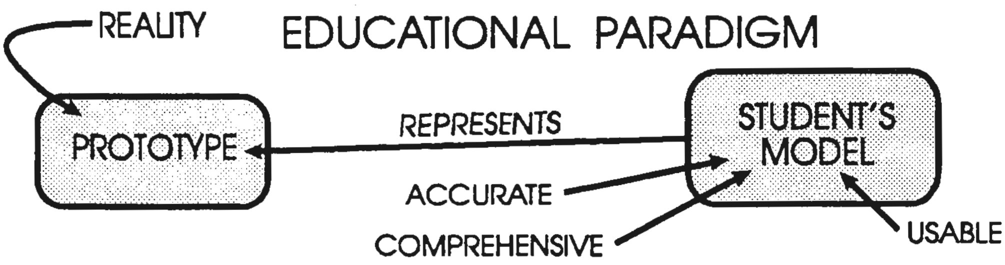
[5] Norman, *Everyday things*, (p. 17).

10.6 EDUCATIONAL PARADIGMS

An educational paradigm has to illuminate the links between the prototype (the real world) and the models which ultimately end up residing in the minds of our students. While the structure of this paradigm is similar in some ways to that described in the computer paradigm, there are a number of significant differences which we will look at shortly.

The intention of learning system design is to provide learning experiences that create in the student an appropriate mental representation of the prototype that is accurate, comprehensive, and usable.[6] The challenge of learning system design is to create learning experiences that bridge the gap between the prototype and the student's model of reality. This parallels the goal of the computer designer who wants to create a user interface which bridges the gap between the prototype he created and the user's model.

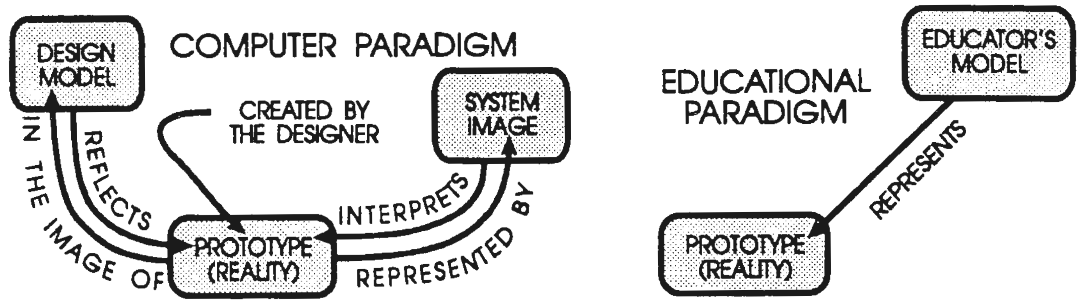


In order to be of value to learning system designers, the educational paradigm is compelled to include the intermediate representations which successively interpret the prototype and transform it into the mental model held by the learner ... often with little validation or feedback. The inclusion of more iterations between the physical reality (the prototype) and the student model both complicates the process and increases the opportunity for misconceptions and errors to creep in. Remember when, as kids, we used to pass secrets from one to another along a row of children at school? What came out at the end of the row usually did not bear much resemblance to what went in at the start.

6 I think this might in many ways be a substantially different intention than in some typical programs which emphasize facts and definitions.

10.7 DIFFERENCES IN THE PARADIGMS; THERE IS NO DESIGN MODEL

In the computer paradigm, the designer *creates the prototype* in the image of the design model. In an educational paradigm, the prototype typically represents an existing reality that is beyond the influence of the educator. The educator teaches things that exist in isolation from his input, a significantly different situation from the computer designer, who specifically strives to create a prototype that matches the design model. There is no design model in the educational paradigm.



This is an important difference from the design context that Norman discusses in POET[7] and with his colleagues in UCSD.[8] In those contexts, the designer creates the prototype, and a major area of concern lies in creating prototypes that by their nature make it easier for a user to develop an appropriate mental model. We in education, however, are usually stuck with someone else's design, be it nature's or society's. We cannot often redesign the prototype. We have to rely on creating strategies to aid the learner in constructing useful models of the objects of interest, regardless of their complexity.[9]

Once the subject matter domain has been defined, value laden curriculum decisions are reached regarding what notions or capabilities should be included in the program as we have seen in Part Three, Curriculum Maps. This would be a sort of layman's model of a domain, and does not have to concern us here. It is what happens next, the more technical aspects, that begin to effect the success of a learning system.

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7 Norman, *Everyday things.*

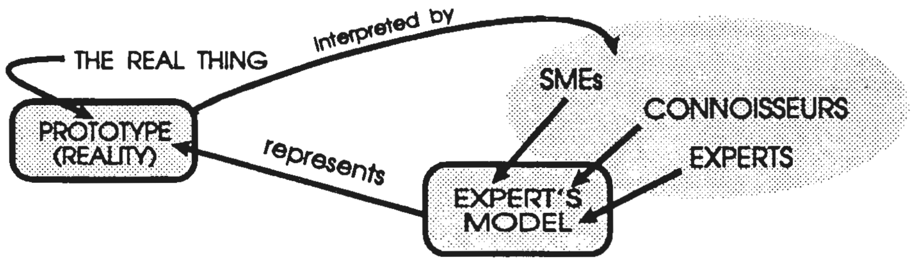
8 Norman & Draper, *User centered systems design.*

9 This is not the situation in designing CML or CAI courseware. Here, the design prescriptions set out in *User Centered Systems Design* can be used to good effect in the creation of computer based instructional systems themselves, not the content that resides within them. See Norman and Draper.

10.8 EDUCATIONAL EQUIVALENT OF SYSTEM IMAGE

The system image in a computer paradigm is the representation of the prototype seen by the user. In our educational paradigm, the equivalent to the system image is the set of learning experiences provided for the student. Underlying these learning experiences is a mental model of the prototype held by the learning system designer or teacher. How should this *instructional model* be derived, and what implications does it have for making notions more teachable? Let's look at what might happen between the prototype and the model that ends up in a student's mind.

An *expert's model* of the domain is used to represent the prototype. This was discussed in Part Three. This expert's model could be developed by a subject matter expert, the venerable SME, by academics, or by experienced practitioners in the field. These experts are expected to provide a comprehensive and mature mental model of the domain based on exploration and experience. This experts' model is the link between the prototype and the educational system, but it is only the first half of the two-step connection from reality to a learner.



Tennyson and Christensen[10] suggest that the purpose of developing an appropriate model is to improve storage and retrieval of student knowledge rather than providing the searching strategies that are the usual goal of knowledge engineers in attempting to locate bits of knowledge. This vision, however, is based on an information processing model which is inconsistent with the Chunque Theory foundation of creating meaningful understanding through the development of progressively more complex and sophisticated mental models beginning with the most stripped down version for novices.

Eisner might hold that the connoisseur would develop a more comprehensive model than the expert that included a larger number of valuing notions. The cognitive representation held by a number of experts (or, better yet, connoisseurs), would comprise our best guess at the nature of reality. This best guess is assumed to reside in the expert's model.

A similar process results in the chart developed under the DACUM process. In this case, the competency profile resulting from the DACUM process constitutes the experts' model of a domain, created by practitioners.

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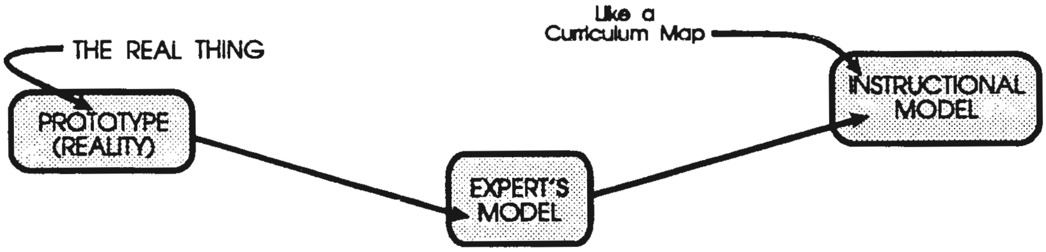
10 Tennyson, R. D., & Christensen, D. L. (1988). MAIS: An intelligent learning system. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 247-274). Hillsdale, NJ: Lawrence Erlbaum Associates.

10.9 ANOTHER INTERMEDIARY

Regardless of the source of the experts' model, the teacher (or instructional designer) relies on this model to provide a comprehensive representation of the prototype. This *experts' model* still must be interpreted and transformed to create an *instructional model*, which is the representation used to create learning experiences. The instructional model, because it is derived directly from the experts' model (and indirectly from the prototype) inherits domain centered qualities and can be assumed to be fairly neat and tidy. The nodes are well defined, the links fairly clear. It is a complex and comprehensive representation. This instructional model is the representation of reality that provides the second half of the link between the prototype and the model we want to create in the student's mind.

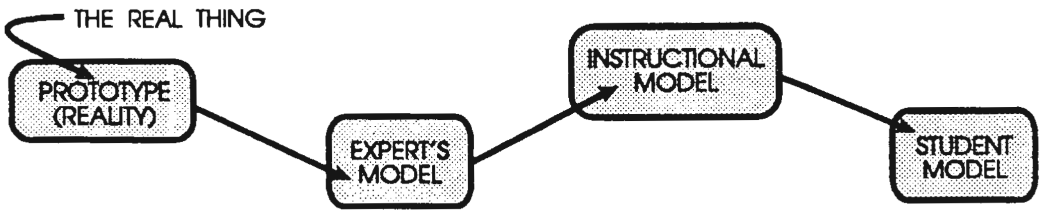


The instructional model is very similar to the curriculum map introduced in Part Six. It is a transformation of the experts' model into a model that is assumed to be more appropriate as a starting point for representing the domain to a student.

The instruction is often designed to transmit this instructional model, more or less intact, to the student. Typically, an optimal student model is viewed by the teacher as being a trimmed down but essentially similar version of this instructional model. I believe this might not be the best thing to do. We will see why shortly.

10.10 THE STUDENT MODEL

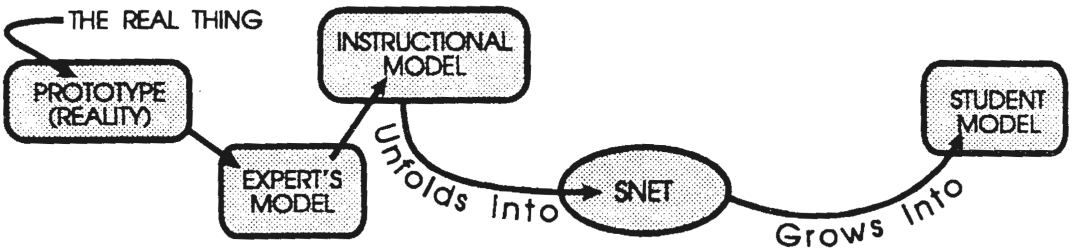
The point of teaching, under the assumptions of Chunque-based learning systems, is to construct a cognitive representation of the prototype within the student which is both appropriate and usable: it must exhibit both accuracy and utility. I will call this representation the *student model.* This student model is the final product of the learning experiences, the complete set of nodes and links which represent the prototype, plus the cross-realm connections to other domains. It is not necessarily a duplicate of the expert's mental model, but usually a less detailed version that provides an appropriate representation for a student competent to begin the long road toward expertise.



The intention is that the instructional model act as an intermediary to interpret the prototype as represented by the experts' model for the student. The end product of a set of learning experiences is an appropriate student model.

10.11 SNETS

Earlier, I spoke of the distinction between a mental model and the underlying semantic network which forms its internal workings. The spaghetti and meatballs which make up the student model is referred to here as an *snet.*[11] An snet is the fluid and changing transitory network of ideas and links that form in the learner's mind as a student model is constructed. The development of an appropriate student model is the goal, the snet is an evolving means of attaining that goal.



The snet held by a student will change over time as a result of learning.[12] I propose that the nature of the learning experiences provided for a student must also change over time, depending on the nature of the developing snet. In the beginning, an snet is likely to be fragmented, incomplete, and often, in many respects, dead flat wrong. It is fraught with errors and misconceptions. Learning experiences should progressively modify this snet so that it becomes less naive, more accurate, more appropriate, and more robust.[13] The initial snet must, in John Seely Brown's terms, provide the seed upon which to grow a more comprehensive and complete model.[14]

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11 This is pronounced ES-NET. You can call it a snet if you like ... its all the same in print.

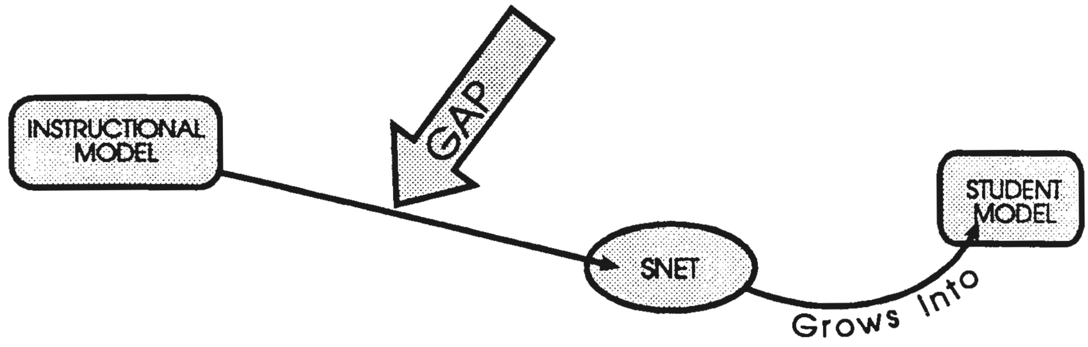
12 I suppose if the snet does not change over time it can be assumed that no instruction has taken place. No, that's wrong. No *learning* has taken place. Instruction often does occur in isolation from learning. This is the distinction between instructional systems design and learning systems design. One tends to focus on delivering instruction, the other on fostering learning.

13 Talk about mental models and cross-realm correspondences! I cannot think of "robust" without connecting it with "Rubenesque." My cognitive metaphor for a robust mental model is a well rounded Rubenesque representation. Bronowski talks about bizarre links like this in Bronowski, J. (1956). *Science and human values*. New York: Harper and Row.

14 Brown, J. S. From cognitive to social ergonomics and beyond. In D. A. Norman & S. W. Draper (Eds.), (1986). *User centered systems design: New perspectives on human-computer interaction* (pp. 457-486). Hillsdale, NJ: Lawrence Erlbaum Associates.

10.12 THERE IS A GAP IN THE PARADIGM

There is a shortcoming with the educational paradigm I have constructed so far. A critical gap exists between the instructional model and the student's model.[15]



This gap exists because, while the instructional model is structured to represent an *expert's* understanding, it can normally be assumed that the student is a naive learner in the domain. Often, the instruction is designed to construct in the mind of the student a mental model that corresponds to the instructional model,[16] to bridge the gap by instilling in the learner knowledge and skills that are assumed to duplicate the mental representation held by the teacher.

In a well organized traditional course, the content that comprises the domain (represented by the instructional model) can be assumed to be laid out in a logical, sequential, rigorous fashion that is "correct" as far as the teacher can determine in all of its aspects. The objective is to transmit this intact to the student. However, this might not be an optimal strategy.

I maintain that the student needs to acquire quite a different and less formal initial version of the instructional model. A tight rigid and rational representation might not be the most appropriate point of contact for a naive learner:

> We shouldn't assume that making careful, narrow definitions will always help children "get things straight." It can also make it easier for them to get things scrambled up. Instead, we ought to help them build more robust models in their heads.[17]

If this is correct, we need a different approach.

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15 Norman discusses these gulfs in *The psychology of everyday things.*

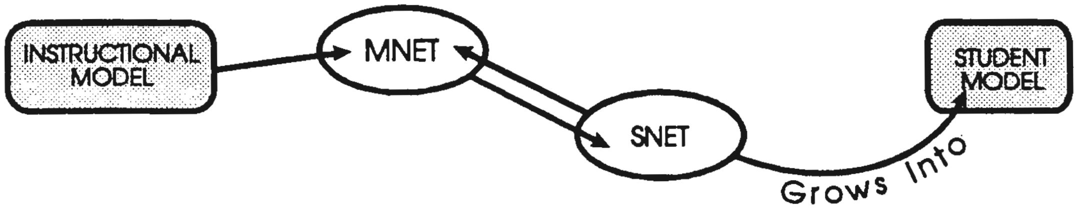
16 Realistically speaking, the instructional model is the only model accessible to the student. How to ensure that this model is appropriate is a teacher education problem, beyond the scope of this work.

17 Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster. (p. 193).

10.13 THE NEED FOR DIFFERENT INITIAL TEACHING MODEL

Minsky suggests that our cognitive representations of reality are not tight logical structures. They are not neat and tidy. They consist of tangled webs of fragments of ideas that are constantly being enlarged, modified, and corrected. We hop around in our minds, forming conjectures and faulty explanations based on incomplete and inadequate information. What begins as a tentative model based on naive perspectives and perceptions is gradually reformulated into more accurate, complex, and consistent structures binding together diverse ideas with convoluted threads of meaning.

Why not assist the student in formulating an optimally appropriate semantic network to foster meaningful understanding of a domain in the sense I discussed earlier? I suggest that the collection of learning experiences that are developed to pass on the teacher's body of knowledge and the structures that form the instructional model be based on a semantic network *specifically designed as a teaching tool* to aid understanding, meaning, and teachability.



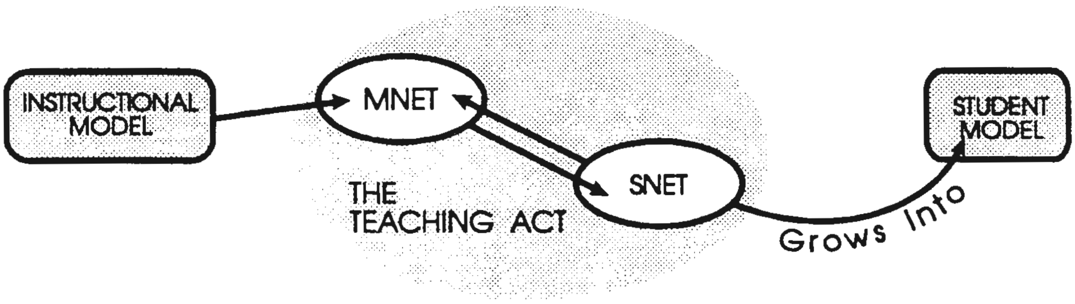
I call this specialized semantic network an *mnet.* It mediates between the instructional model and the learner model. It relates to the instructional model in the same way an snet relates to the student's model: it is a model that starts as a simplified representation of the instructional model and provides a seed upon which to grow further understanding and meaning.

10.14 BRIDGING THE GAP

A few pages back, I recalled the example of passing a secret from child to child, and how it changed along the way. When we examine the number of transformations or iterations between the prototype and the final representation that I call the student model, it would seem that we are ripe for messed up secrets.

But here is an interesting point: where in this chain of representations does the teaching act reside?

I believe the act of teaching bridges the gap between the mnet and the snet. Teaching is the act of sliding the nodes and links of the specially designed mnet representation across to the carefully nurtured snet. The closer the match between the unfolding mnet and the growing snet, the more effective the teaching.



Now, the success of this depends to a great extent on two things. The mnet must be a really good representation to unfold ... it must be teachable and learnable. Assuring this is so is the job of the learning system designer.

Also, the learning experiences that are used to help the student incorporate the nodes and links of the unfolding mnet into an evolving snet must be really good. Designing these learning experiences is also partly the job of a learning system designer. Carrying these learning experiences to the student is the job (or, as Eisner would say, the *art*) of the teacher.[18]

[18] Eisner, E. W. (1985). *The educational imagination* (2nd ed.). New York: Macmillan.

10.15 MNETS

An mnet is a special semantic network created for the express purpose of providing an appropriate and optimally "learnable" representation of a knowledge structure for a student. Teachers and designers can create these to bridge the gulf between the existing instructional model and the desired student model. Minsky says:

> What can we do when things are hard to describe? We start by sketching out the roughest shapes to serve as scaffolds for the rest; it doesn't matter very much if some of those forms turn out partially wrong. Next, draw details to give those skeletons more lifelike flesh. Last, in the final filling-in, discard whichever first ideas no longer fit.[19]

An mnet is a simplified version of the instructional model. It might be what Bruner had in mind as the initial pass in his learning spirals when he suggested that we can teach anything in some intellectually honest fashion to any student at any age.[20] An mnet is evolutionary in a temporal sense, growing from an initial seed that represents the most simple and general network of ideas that illustrate the domain. An mnet actually unfolds more than evolves, assuming that the mnet was designed ahead of time.

Norman, speaking of the computer paradigm, illuminates the need to provide appropriate models for teaching:

> People are very good at forming explanations, at creating mental models. It is the designer's task to make sure they form the correct interpretations, the correct mental models: the system image plays the key role.[21]

The system image here corresponds to what I am calling an mnet, the aspects of something visible to the learner. The nature of an mnet must be such that it makes learning easier:

> ... a useful representation must be cognitively transparent in the sense of facilitating the user's ability to "grow" a productive mental model of relevant aspects of the system. We must be careful to separate physical fidelity from cognitive fidelity, recognizing that an "accurate" rendition of the system's inner workings does not necessarily provide the best resource for constructing a clear mental picture of its central abstractions.[22]

An mnet is used to transform the complex and rigorous teacher model into a preliminary seed of partial but plausible understandings upon which the student can eventually grow a comprehensive conceptual model.

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19 Minsky, in the prologue to *The society of mind,* (p. 17).

20 Bruner, J. S. (1966). *Toward a theory of instruction.* New York: Norton.

21 Norman, *Everyday things,* (p. 198).

22 Brown, *Cognitive ergonomics,* (p. 478).

10.16 MACRO-LOGISTICS AND MNETS

Macro-logistics is the study of instructional strategies concerned with sequencing many ideas. The unit of interest in macro-logistics is the Chunque. Mnets hold the promise of becoming valuable tools in the design of optimal sequencing strategies in the creation of customized paths through a network of learning experiences. They provide a means of organizing subject matter for a holographic logistics strategy.

Each Chunque is a network of ideas that form a somewhat separate mental model.[23] A number of chunques are related in various ways to form higher level mental models, much like the different levels of meaning that Minsky describes. The connections between Chunques are the cross-realm correspondences, the external links between mental models. The manner in which Chunques are postulated to interrelate is very similar to the internal links which connect the nodes within a Chunque ... it seems to be a matter of scale.

Earlier on, we looked at different structural metaphors. We explored the specific-to-general sequence (a cumulation strategy), which I related to the "bricks in the temple of knowledge" strategy, the prerequisite strategy, the spiralling strategy of Bruner, and the elaboration strategy of Reigeluth and Merrill. Each of these takes a similar tack. The pieces of content (chunques) are organized into some kind of hierarchical structure, and the possible paths through the structure are constrained by the organizing strategy. In some designs, the path is linear, in others a number of possible path sequences are available. But there are always constraints on the next-Chunque choices available to the learner (regardless of whether it is the learner or the teacher who makes the choice).

An omission in the majority of multiple-path designs, however, is a strategy for selecting which of the next-Chunque choices is optimal. In particular, Merrill identifies the lack of prescriptions for course organization. He emphasizes that we need, but do not have, global models for sequencing course content.[24]

Applying the mnet notions developed here to macro-logistic path strategies provides some possible guidelines for next-Chunque prescriptions. I will base these proposals on the elaboration hierarchies used in the Reigeluth-Merrill Elaboration Theory[25] because I believe that a general to specific, simple to complicated structure provides a better framework for the orderly development of an snet.

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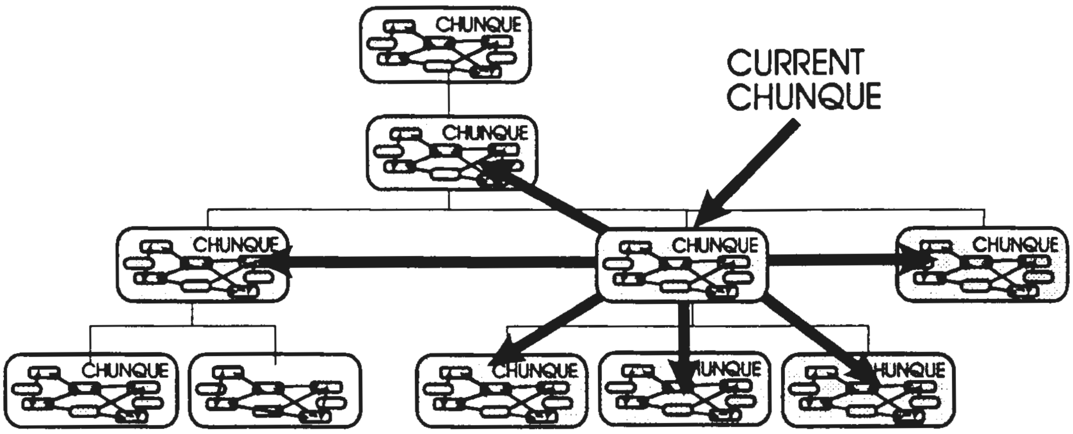
23 See Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates.

24 Merrill, M. D. (1989, June). Paper presented at the annual convention of the Association for Media and Technology in Canada, Edmonton, Alberta.

25 Reigeluth, C. M., & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 335-381). Hillsdale, NJ: Lawrence Erlbaum Associates.

10.17 MNETS AND REIGELUTHIAN ZOOMS

The Elaboration Theory organizes pieces of content (similar in nature to Chunques) into a hierarchy best expressed by the familiar zoom lens analogy.[26] The value of this analogy is suggested by Minsky's comment on an agency in the brain looking in on our thought processes and saying, "This isn't getting us anywhere: move up to take a higher-level view of the situation" Or it might say, "That looks like progress, so move farther down and fill in more details."[27] The possible paths available to students under the Elaboration Theory are constrained by next-Chunque rules which state that the next-Chunque must be either directly subordinate to the current Chunque, directly superordinate to the current Chunque, or coordinate with the current Chunque. However, the Elaboration Theory does not provide prescriptions for which of the possible next-chunque choices are optimal. This diagram developed from Locatis, Letourneau and Banvard[28] illustrates the possible next-Chunque choices:



Upon completing the current Chunque, a student could progress to any one of the group of directly related Chunques, as indicated by the arrows in this diagram. The Elaboration Theory therefore constraints the student to move to a related Chunque. Notice that, if the student moves *up* to the top Chunque in this diagram, it would be to synthesize the new subject matter. The student would have already mastered the top Chunque, or he or she would not have been able to get to the current one.

Elaboration hierarchies are based on a single kind of relationship. The nature of the connecting links between the chunques in a given elaboration hierarchy are one (and only one) of either procedural links, conceptual links, or theoretical links.[29] The nature of the links is such that the chunques form a hierarchical structure from general at the top to detailed at the bottom.

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26 Reigeluth, C. M. (Ed.). (1983b). *Instructional-design theories and models: An overview of their current status.* Hillsdale, NJ: Lawrence Erlbaum Associates.

27 Minsky, *The society of mind,* (p. 92).

28 Locatis, C., Letourneau, G., & Banvard, R. (1990). Hypermedia and instruction. *Educational Technology Research and Development. 37* (4), 65-77.

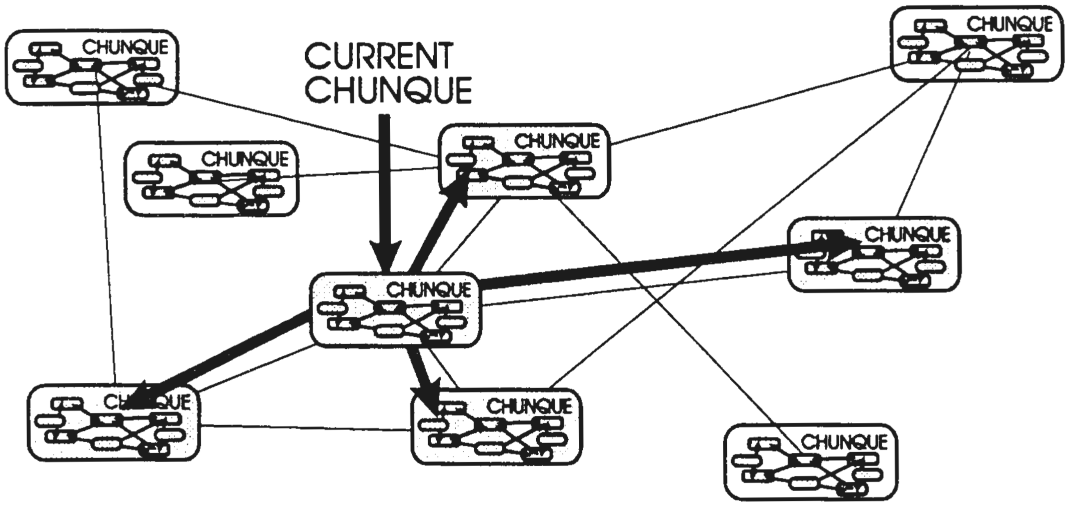
29 Reigeluth & Stein, *Elaboration theory.*

10.18 RELATIONAL ELABORATION NETWORKS

I suggest that three extensions to these elaboration structures might accommodate the notions expressed earlier about the nature of MNETS. First, the hierarchical structure might be replaced by a *relational network* of Chunques that still follows a general to specific, simple to complex design. Second, the constraints that result from the nature of the connections between Chunques might be less rigid, incorporating many kinds of cross-realm correspondences. Third, prescriptions for optimal next-Chunque choices used to create a path within the constraints of the structure should be based on the significance of the link to the learner.

A relational network differs from a hierarchical structure primarily in that it is a multi-dimensional web of Chunques and connections that constitutes a less rigid set of relationships among the Chunques. The use of a relational structure to construct an mnet provides a wider variety of ways to form connections which express the nature of between-Chunque relationships to the learner. This is consistent with Minsky's proposition that we do not learn to construct meaning through rigid, rational and logical rules.

This diagram, also drawn from Locatis, Letourneau and Banvard, is somewhat like a relational network and illustrates the possible next-Chunque choices: it does not qualify as a true relational network in Denenberg's terms, since the nature of the links is not indicated.[30]



The interrelationships among the Chunques is indicated by the narrow lines. Notice that the next-Chunque choices are still constrained to a group of directly related Chunques.

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[30] Denenberg, S. A. (1988). Semantic network design for courseware. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 307-326). Hillsdale, NJ: Lawrence Erlbaum Associates.

10.19 THE NATURE OF BETWEEN-CHUNQUE LINKS

Not only is a more network-like array of connections between Chunques proposed as a way of making the mnet more learnable, but the mnet might prove more teachable if the nature of the links was not limited to only one of theoretical, procedural, or conceptual relations. Perhaps a multitude of different but *significant kinds* of links would ease initial understanding of a scaffolding of relationships for a learner. These might perhaps form a series of overlapping distributed and context-sensitive models that could be synthesized later into a more tightly structured single-relationship network proposed by the Elaboration Theory. The reformulation of an initial messy semantic network into a more logical and rational model appears to be consistent with the mental processes described by Minsky, Norman and the other authors noted here.

At this time, how much freedom should be permitted in the kinds of links is an open question. In the SEMNET program for the Macintosh demonstrated by Brock Allen,[31] any kind of link can be established, limited only by the whims of the creator. Merrill has suggested that this may not be appropriate for instructional design models. He would constrain the kinds of links to those appropriate for the development of instruction, but has not yet suggested what the nature of those appropriate links might be.[32] A more tightly constrained semantic network model is the rule-based expert system which uses a computer program to develop an *internally consistent* set of relationships based on rigid rules.[33] Relational networks developed under a rule-based system are guaranteed to be internally consistent because the system will not allow the designer to add links that are "wrong" in the sense that they are outside of the allowed types or cause a logical inconsistency within the network.

Where along this continuum from total freedom to rigid constraint to set the optimal limits on mnet connections has yet to be determined. I lean toward the less structured pole, because I tend to buy in to Minsky's proposition that beginning learners create meaning through a tangled web of ideas and cross-connections that are not developed through tight logical reasoning.[34] The rational structures of mature mental models seem to me to derive from reformulations of our initially confused and inconsistent explanations.

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31 From Allen's presentation on the SEMNET computer package at the Canadian Centre for Learning Systems symposium series, Calgary, Alberta, March 16, 1989.

32 From Merrill's presentation at the Utah State University summer institute, July, 1989, Logan, Utah.

33 Mark, W. (1986). Knowledge-based interface design. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 219-238). Hillsdale, NJ: Lawrence Erlbaum Associates. (p. 351).

34 "The world does not encourage a perfectly rational lover, simply because a perfectly rational lover would never get married. The world does not encourage a perfectly rational army, because a perfectly rational army would run away." Gilbert K. Chesterton, cited in Minsky, *The society of mind*, (p. 300).

10.20 OPTIMAL INITIAL MNET STRUCTURES

I suspect, although I have been unable to uncover much work in this area, that the typical prescriptions for selecting which links to teach first are based on logical or rational considerations. The strongest logical links would be explored first, for instance. This is a domain centered notion, usually hierarchical, based on a sanitized expert perspective of the system, which Minsky and Norman suggest may not be the most appropriate initial contact in terms of teachability.

I propose as an alternative a student centered perspective. The developing student model (the snet) should be based (as suggested by the Elaboration Theory) on an mnet that begins with the most simple and general Chunque that is likely to be relevant to the student.[35] Then, when zooming in, the choice of which Chunque within the range of choices available in a relational elaboration network to explore next should be based on the most *significant* links from a *student* perspective. I suggest that an appropriate way to determine the kind of path to create through the cluster of Chunques organized into an elaboration network should be based on the *nature of the links* between the Chunques. This proposition contains two elements: the notion of *significance*, and the notion of *student perspective.* I would construct an mnet by refining the instructional model, based in part on the principles of the Elaboration Theory which suggests starting with the most general, simple, and concrete representations. In this way, the instructional model, which is assumed to be based on a complex and expert domain-centered picture of a rational structure, would be transformed to create an mnet which linked the nodes depending on the anticipated significance to the student of both the adjoining nodes and their connections. I assume that the most significant links would form the strongest connections for the learner. This would help construct an attractive snet because it is relevant to the student; it would provide a context.

This extends the prescriptions of the Elaboration Theory to form a plausible and growing seed of Chunques and interrelationships that address the dual considerations of understanding and meaning. It would also seem that the initial simplified student model would represent a workable model of the prototype that was robust in the sense that the structure had meaning (dependent upon a wider contextual perspective) to the learner.

Just how to work out which links would likely be more significant to the student and what content to place within each Chunque of an elaboration network remains a mystery. Many powerful suggestions can be gleaned from the five books mentioned in the introduction to this work in section 2.2. At this point, the general thrust of my investigations center on the ideas of developing a less rigorous framework, a structure based on the plausible rather than formal tight logic, and the compelling notion of distributed models suitable for fragments of an mnet that can be reassembled later.[36]

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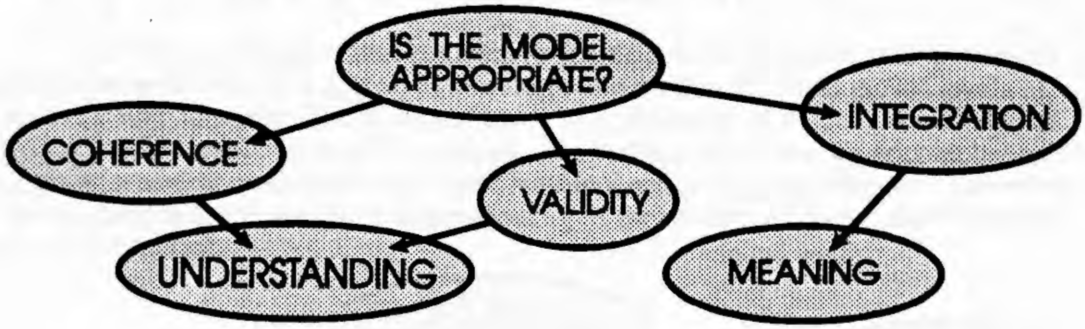
[35] In a course, this would be a synthesizing Chunque in the *Home Base*. This is supported by John Keller's ARCS model. See Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum Associates.

[36] This draws on Reigeluth's notions about synthesizers used in the zoom out phase of the elaboration theory to bind new ideas into the previous structure. See Reigeluth & Stein, *Elaboration theory.*

10.21 VERIFYING THE NATURE OF A STUDENT MODEL

What does it mean when we say we understand? "A direct outcome of the analyses presented here is a view of understanding as a multidimensional quality rather than something one has or does not have."[37] "The power of mental models is that they let you figure out what would happen in novel situations."[38]

Determining how to assess the extent to which a student model is appropriate requires consideration of both the internal aspects of the model, to assess understanding, and the external connections with other realms of understanding to assess meaning. Mary Riley discusses three aspects of assessment which address both of these issues; coherence and validity (internal), and integration (external).[39]



Internal coherence is the extent to which components of knowledge are related to a consistent internal structure. Riley suggests that the value of a model depends on whether it allows a student to infer how-it-works understanding. "Neither details about the nature of the components, nor general principles about how a system work enable users to infer [correct] procedures."[40]

A promising verification tool that I have encountered for this type of assessment is suggested by the work of Renate Lippert.[41] In Lippert's experiments engineering students create rule based expert systems to explain their understanding of physics principles, such as the rules governing the trajectories of ballistic objects. At the 1988 AECT conference, she had a number of us create (in an afternoon) an expert system to explain our reasoning in answering the question "can I copy this disk?" This strategy ties in nicely with the notion of clarifying and cleaning up a mental model by reformulating and restating it in a different form. I believe that the use of currently available easy-to-use expert system shells as demonstrated by Lippert's work provides great promise as a tool for assessing the nature of the mental models held by our students. It is a powerful methodology that gets to the nub of understanding.

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37 Riley, *User understanding*, (p. 169).

38 Norman, *Everyday things*, (p. 71).

39 Riley, *User understanding*.

40 Riley, *User understanding*, (p. 164).

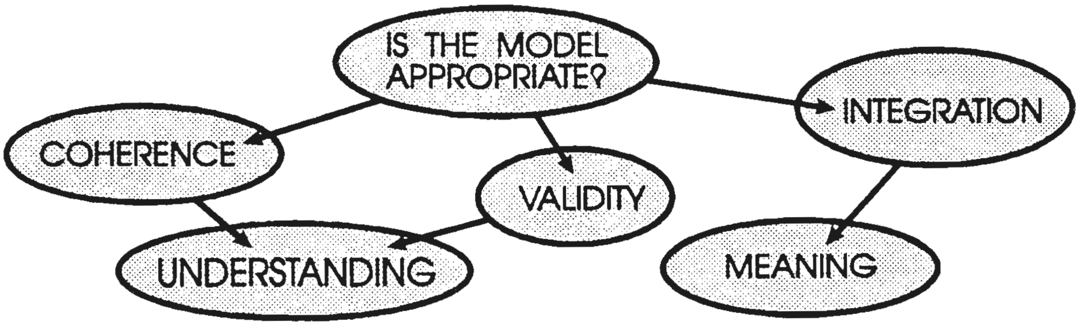
41 Lippert, R. C. (1989). Expert systems: Tutors, tools, and tutees. *Journal of computer based instruction, 16* (1), 11-19.

10.22 VALIDITY AND INTEGRATION

Validity is the extent to which the student's knowledge is consistent with the prototype. This is the quality that allows the student to explain and predict. Validity does not depend on whether the student model is identical to the prototype, as long as the model leads to accurate predictions. A major problem with invalid models is that people are very adept at generating context-dependent validity to achieve coherence at the expense of accuracy. Appropriate models must be *generally* accurate. Riley states:

> Initial component models invariably include implicit assumptions which may or may not be correct. With experience, component models become more robust by making implicit assumptions explicit. This transition is driven by discovering violations of consistency and validity.[42]

This seems to suggest that summative (certification) assessment of a student's mental representations of a prototype should be directed at the most global levels of structural understanding. The more reductionist assessment of student knowledge of individual nodes and links is still important, but perhaps this could be accomplished through informative evaluation embedded within the learning experiences. The proof of the pudding is in the student's understanding of the structure and relationships that make up the model.



Integration is the extent to which components of knowledge and understanding in one domain are tied to other realms of the student's knowledge. Assessment of integration may best be served by evaluating the student's understanding of the significance of one Chunque in relation to others and through "compare and contrast" type questioning. The essential element here is to assess the extent to which the student can position new understanding within a wider context.

42 Riley, *User understanding,* (p. 166).

10.23 CONCLUDING REMARKS

My particular area of interest is in using these thoughts on the development of mnets as mediating structures between domain knowledge (as it resides in instructional models) and student models. I believe that much further work is required to understand the qualities and characteristics of the many kinds of links that connect the nodes of our mental models. An understanding of the nature of these links could lead to a better understanding of what makes some more significant than others in the students' eyes. Still unanswered is the question of whether the kinds of links that are used to form an mnet should be unfettered, limited to only particular appropriate kinds, or constrained into internally consistent rule-based networks. The qualities of the nodes and the instructional strategies that are used to design within-Chunque transactions are the focus of considerable research at this time[43] but investigations centered on among-Chunque strategies to optimize the path of a student through a series of learning experiences are evident by their absence.

My work is centered on the development of strategies to chart a course for a learner through a network of learning experiences. I am formulating my own mnet about learning systems, what they should be and what they should do. These investigations, begun at The Canadian Centre for Learning Systems and continuing at Lakeland College have led to concerns with computer managed learning, with assessment measures and their relationship to program goals, to competency based education and the serious problems with reductionism, and John Seely Brown's[44] comment that it is easy to convince someone intellectually about the worth of a new idea, but it is entirely a different thing to substantively alter what they do.

A final note on reductionist approaches: Minsky states that feature-weighting machines (computer systems that can recognize characteristics of objects) cannot distinguish between things when information about relationships has been lost. I think this relates to reductionist approaches to instruction. I believe the fine-grained reductionist view provides valuable analysis tools for the designer, but should not necessarily be the focus of instruction. To get at meaningful understandings, I agree with Merrill's contention that we must look at larger units of knowledge. Behavioral objectives and competency based education schemes promote an unfortunate bias toward teaching independent fragments of knowledge *because that is what we typically assess to ensure competence.* But that is not all that we should teach. If the students can gain knowledge of the web of relationships that comprise meaningful understanding, they will be able to answer the reductionist questions as well as the more crucial questions of what it all means.

To know is to have access to an appropriate mental model.

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[43] Merrill, *Expert systems.*

[44] Brown, *Cognitive ergonomics.*

AFTERWORD: ON THEORY BUILDING

ON THEORY BUILDING

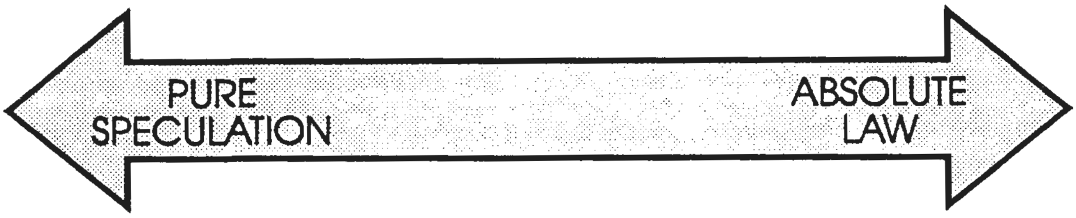
How do we build theory? The exploration of how educational theories are built, what they are, and why they are as they are leads to a morass of conflicting notions and a tangled web of deep seated propositions inherited from the hard sciences. To explicate where *this particular theory* fits within this framework would become a book in itself. But this work is not *about* theory building. It *is* theory building. This work is not a descriptive metatheory about theory building, but an example of the construction of one particular theory which provides a plausible explanation of the underlying principles and guidelines for the management of instruction.

How do we build theory? An investigation of theory building leads to definitions of kinds of theories and descriptions of the kinds of building processes used to create them, such as the inductive versus deductive approaches described by Reigeluth[1] or the distinction between decision oriented and conclusion oriented research suggested by Jackson.[2] Kuhn describes the development of theory from the multiple paradigms of an immature science to a single and more universal paradigm which grows with maturity.[3] Tazelaar[4] sees the process of theory building as a choice between paradigms, a "whole new way of looking at things," while Shavelson speaks of shifting mindframes.[5]

Reigeluth[6] proposes that theoretical propositions range in certainty from pure speculation to absolute law. The difference is in the degree of confidence that we have in the propositions:

> [A principle] may be *deterministic*, in which case the cause always has the stated effect, or it may be *probabilistic*, in which case the cause sometimes (or often) has the stated effect. Finally, the term *principle* is used here regardless of the degree of certainty of the relationship. Hence, it includes everything from pure conjecture or hypothesis (having little or no evidence for its truthfulness) to scientific law (having much evidence for its truthfulness).

Thus, the degree of certainty regarding the truthfulness of a proposition can be seen to range along a continuum from pure speculation to absolute law:



1 Reigeluth, C. M. (1983a). Instructional design: What is it and why is it? In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 3-36). Hillsdale, NJ: Lawrence Erlbaum Associates.

2 Jackson, P. W. (1990). The functions of educational research. *Educational Researcher, 19* (7), 3-9.

3 Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

4 Tazelaar, J. M. (1990). Object lessons. *Byte, 15* (10), 206. (p. 206).

5 Shavelson, R. J. (1988). Contribution of educational research to policy and practice: Constructing, challenging, changing cognition. *Educational Researcher, 17* (7), 4-11.

6 Reigeluth, *Instructional Design: What is it*, (p. 14).

The role of theory and research can be viewed as lying along this continuum. At the pole of least certainty lies the activity of *theoretical speculation.* At the other pole resides *experimental research.* Linking the two is *theoretical research.*

At the speculative end of the continuum there are theoretical propositions which seek to make sense of things in the most tentative ways. At the other is empirical research, charged with the responsibility to verify the degree of certainty that can be attached to theoretical propositions.

Speculative theory can be described as the initial and tentative step in discovering new linkages that connect existing notions in new ways to provide what might be a better explanation of why things are as they are. Gleick[7] says the theoretical scientist dabbles with ideas (notions in the mind) while the experimental scientist dabbles with things (objects in the real world). Bronowski[8] describes the act of creativity as discovering new connections between ideas in ways that were previously unknown. Speculative theory building is such an activity. The role of the speculative theorist is to dabble with the most tentative and unexplored connections to discover new ways of linking ideas. These links between previously disparate ideas are the propositions that might ultimately become the heart of the experimental scientist's hypotheses. The speculative theorist is charged with providing more adequate models of Simon's[9] *plausible* explanations of reality. The experimental researcher is charged with finding evidence to support progression of these models along the Reigeluthian continuum from conjecture towards law.

The product of a speculative theorist is a tentative framework upon which to build a model of reality. This framework is much like the initial mental models described by Brown, Norman, and Minsky.[10] It is characterized by sense making in a more global perspective. The initial model emphasizes the relationships between the parts rather than focussing on the parts themselves: theoretical speculation tends to be less reductionist or atomistic in focus than empirical research.

Speculative theory construction results in an integrated collection of propositions that combine to form the genesis of more specific propositions, strategy components, and methods that can be used in particular instances. *Theoretical research* transforms the tentative propositions of the speculative theorist into more precise propositions based partly on reason, partly on logical consistency, and partly on

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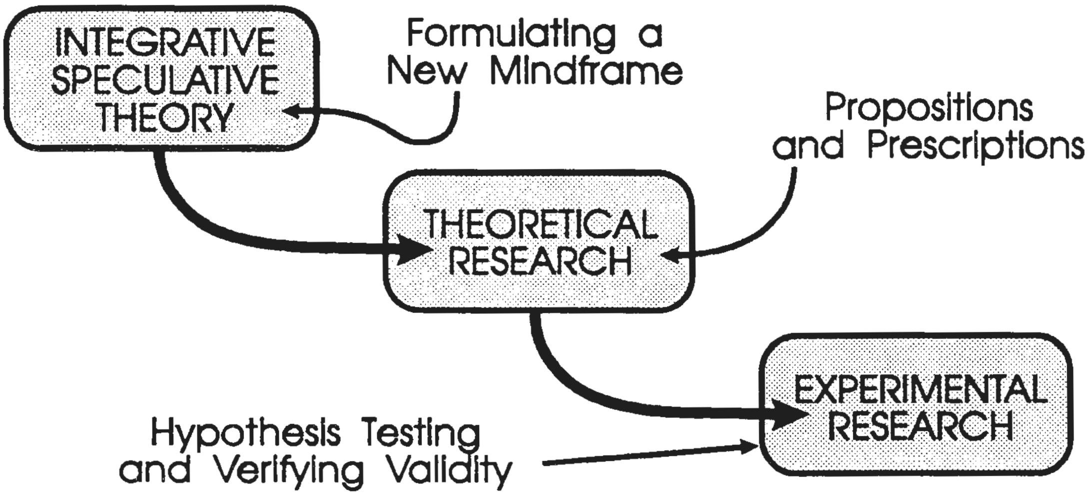
7 Gleick, J. (1987). *Chaos: Making a new science.* New York: Viking Penguin.

8 Bronowski, J. (1956). *Science and human values.* New York: Harper and Row.

9 Simon, H. A. (1981). *The sciences of the artificial* (2nd ed.). Cambridge, MA: MIT Press.

10 See Brown, J. S. (1986). From cognitive to social ergonomics and beyond. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 457-486). Hillsdale, NJ: Lawrence Erlbaum Associates; Norman, D. A. (1988). *The psychology of everyday things.* New York: Basic Books; and Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster.

consistency with existing empirical evidence.[11] These prescriptions, methods, and propositions can also range in certainty from speculation to law. In either case, it is the propositions of the theoretical researcher (which can be derived from speculative theory) which become the hypotheses that are tested by experimental researchers in the real world. Thus there are three levels here: the integrative speculative theorist tries to fit things together in new and tentative ways to make sense and to change or create a new mindframe. The theoretical researcher tries to transform these into more particular propositions and prescriptions that are less speculative. The experimental researcher tests the validity of these propositions as they become hypotheses for research.



Recently, the adequacy of empirical research methodology in providing such movement in social science phenomena has come into question. Statistical significance, a corner stone of the empirical method, has been described as only one of several recognized tests of internal validity. The importance of internal validity as a necessary or sufficient prerequisite to external validity has been attacked by House, Mathison, and McTaggart.[12] They propose that for the practitioner, the linkages between internal validity, external validity and application are suspect, and go on to suggest the concept of *intentional causality* as a plausible alternative to the Humean regularity theory of causation, which states that cause and effect relationships can only be inferred from repetition, regularity, or universal causal laws.

Intentional causality proposes that cause and effect can be *logically* related to one another, that causality does not necessarily and exclusively depend on the existence of universal causal laws, and that cause and effect can be known through a single experience. This notion of intentional causality might be at the heart of speculative theory and Simon's suggestion of plausible human action.[13]

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11 See Reigeluth, *Instructional design: What is it*, and Gropper, G. L. (1983b). A metatheory of instruction: A framework for analyzing and evaluating theories and models. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 37-53). Hillsdale, NJ: Lawrence Erlbaum Associates.

12 House, E. R., Mathison, S., & McTaggart, R. (1989). Validity and teacher inference. *Educational Researcher, 18* (7), 11-15, 26.

13 Simon, *Sciences of the artificial.*

A MODULAR THEORY

What has this to do with learning systems theory? I believe that we can develop general theoretical stances, sort of metatheories, that outline the kinds of things that we must address, and we can plug in what we suspect are appropriate strategy components for each of the slots in the metatheory. This is what I have tried to do here with instructional logistics concerns.

The Chunque Theory is a metatheory in this sense, where I have tried to identify the cardinal principles, which are really the slots into which can be slipped the most appropriate strategies. What these strategies are will depend upon the flavour of the moment. The more sophisticated our design tools become, such as through computer managed learning and adaptive instructional techniques, the more appropriate will be our instruction-of-the-moment. Gleick characterizes this as the distinction between generalities and instances in systems which are globally stable but locally unpredictable.[14] This is the situation in which we find ourselves. Our instructional design propositions tend to be globally stable, but locally unpredictable. The general structure that guides the kinds of things that must be addressed can be identified in a globally stable way, but the particular strategy components that should be used in any given instance will vary depending on the particular circumstances and, over a longer term, on the sophistication of our knowledge base.

What I am suggesting is that the speculative theorist constructs this framework of new connections, a new mental model, that describes the kinds of things that must be addressed and how they fit together to optimize a learning system. Then the theoretical researcher investigates each of the slots (nodes) in the model to discover the current state of our understanding and to specify the range of possible strategy components that can be slipped into each node.

This plug-in model splits the determination of certainty in to discrete parts. In one instance, the validity of the structural model, which seeks to identify what parts or issues must be addressed, and structures these parts into a framework of slots, can be investigated. As a separate issue, the selection of optimal strategy components to fit into each of the slots can be evaluated. This, I believe, reflects the perspective proposed by Gropper when he suggests that it is more important to address *that* some form of strategy component is used than to be concerned with *what* that component is.

The sense making of the speculative theorist is initially guided, I believe, by intuition and experience. Ideally, the speculative theorist is a *connoisseur* in the Eisnarian sense.[15] The nodes and links of the initial models seem plausible and appear to provide a better understanding of a domain. They have face validity.

The theoretical researcher digs further into the existing knowledge base to validate the propositions of the speculative models based on criteria such as those

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14 Gleick, *Chaos*.

15 Eisner, E. W. (1985). *The educational imagination* (2nd ed.). New York: Macmillan.

suggested by Reigeluth.[16] The experimental researcher can then construct experiments to verify the truthfulness of these propositions and suggest which might be most appropriate in particular situations.

This is why I believe we are compelled to strive for adaptive learning systems which customize instruction on the fly to respond to the circumstance of the moment. The Chunque Theory stresses the structure and the relationships among the various bits and pieces of instructional design theory that relate to the management of learning. This can result in a fluid theory which grows and changes as our knowledge matures. Our mental model of education and instruction becomes increasingly more robust.

In writing this work, I was primarily concerned with identifying what the necessary and sufficient bits and pieces are and then looking around to find out what seemed to be the best available knowledge about each piece. In this regard, the Chunque Theory is partly based on speculative theory and partly on theoretical research. But it must be emphasized that it was the identification of the pieces and how they fit together that was the primary motivation for writing this book. It is impossible for one person over six years to explore in detail the knowledge base for all of these pieces. At the Canadian Centre for Learning Systems we did the best we could through the symposium series, the literature reviews, and contact with our colleagues. But the structure, the framework, is the important thing to foster a change the mindframe. It is a fairly simple matter to incorporate strategy components that I missed within this framework. The judgement of the success of this work should be based on the degree to which this theoretical framework provides a scaffolding for a new mindframe and a new way of leaping the chasm from the value-laden goals of the stakeholders to the anticipated future accomplishments of the graduates. This work emphasizes the links, not the nodes: here is the spaghetti ... you find the meatballs.

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16 Reigeluth lists eight criteria for evaluating theories of instruction: Internal consistency, explicit boundaries and limitations, not contradicted by data, parsimony, usefulness, comprehensiveness, optimality, and breadth of applicability.

KINDS OF THEORIES

Reigeluth makes a clear distinction between *descriptive* and *prescriptive* instructional theory.[17] Reigeluth sees these types of theory lying along a continuum which ranges from pure descriptive theory on one end to pure procedures on the other. Prescriptive theory lies somewhere between the two.

In descriptive theory building, the theorist defines the conditions under which a situation exists and the methods used in instruction, and constructs (or seeks to discover) an explanation of the outcome. A *descriptive* theory is an after-the-fact explanation of why things occurred as they did.

Procedures, at the other end of this continuum, are step be step directions for producing a particular result in a particular situation, such as rebuilding a transmission.

In prescriptive theory building, the theorist defines the conditions and the anticipated outcomes, and suggests appropriate methods which are expected to produce the desired results. A *prescriptive* theory is a before-the-fact explanation of what to do and why to do the things the theorist predicts and expects will produce the desired results.

I suspect there are two differences between procedures and prescriptive theories. Procedures are usually verified steps for producing particular results, and do not need to include explanations of why they work. One can carry out a procedure without an understanding of why the steps are done as they are. Prescriptive theories, on the other hand, should include (and in fact are centered upon) Riley's[18] how-it-works knowledge.

Procedures also tend to have more certainty attached to the steps and results. Prescriptive theories are somewhat more tentative, dealing with anticipated results, usually in more complex situations.

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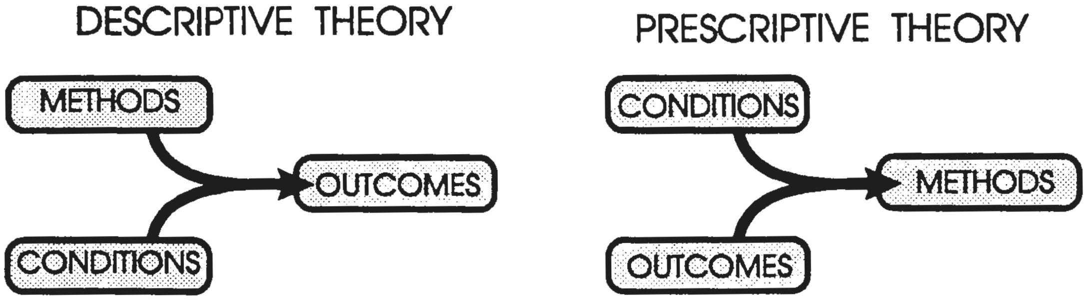
17 Reigeluth, *Instructional design: What is it.* Barbara Martin and Les Briggs extend the use of the terms descriptive and prescriptive to refer to *taxonomies* in their 1986 book *The affective and cognitive domains: Integration for instruction and research.* Englewood Cliffs, NJ: Educational Technology Publications.

18 Riley, M. S. (1986). User understanding. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 157-170). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth[19] expresses the difference between descriptive and prescriptive theory with these two diagrams:



In descriptive theory, the methods and conditions are given, and the *outcome* is the variable of interest. Descriptive theory is goal free. In prescriptive theory, the conditions and desired outcomes are given, and the *methods* are the variable of interest. Prescriptive theory is goal-driven in the sense that certain outcomes are viewed as desirable, and the point of the exercise is to predict which methods are most likely to produce the desired result.[20]

The Chunque Theory contains elements of both descriptive and prescriptive kinds of theory, but very little in the nature of procedures. It is descriptive in the sense that it seeks to provide new explanations of why things happen as they do, and prescriptive in the sense that it seeks to provide guidelines that will assist instructional designers in selecting optimal methods to guide learners through instructional programs. However, the primary goal of this work is to provide propositions that will combine to create a new way of viewing the management of instruction. It is a speculative theory about instructional logistics that may provide a new mindframe for practitioners, and provides propositions which can become preliminary hypotheses for experimental researchers.

In a mature science, Kuhn[21] suggests the growth of a single and predominant paradigm which accommodates newfound knowledge until internal inconsistencies become so great that a sudden revolution results in the adoption of a new and more adequate explanation of how things are. James Gleick[22] anticipates the "one great experiment" which overthrows the old order. In most of this literature, theory building in the hard sciences predominates: few draw the distinction between theory in natural

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19 Reigeluth, *Instructional Design: What is it.*

20 An interesting point here is the third possible combination of these three variables. What do we have if the methods and outcomes are considered as givens, and the conditions are the variable of interest? It occurs to me that this might be the nub of the problem with the educational system. We have existing methods in the schools, and fairly clear ideas about the desired outcomes. Both of these are fixed, in the sense that few people hold much hope of fundamentally changing either of them. In order for the existing methods (our educational system) to satisfy the expected outcomes, what must the appropriate conditions be? The system seemed to work better when the conditions, such as our cultural perspective, the nature of the students, and the economic and social framework were different. Perhaps this is our problem: we might be thinking of methods and outcomes that will not work under current conditions.

21 Kuhn, *Scientific revolutions.*

22 Gleick, *Chaos.*

science and theory in what Simon[23] calls the *sciences of the artificial.* I believe this is because the hard sciences deal in generalities. What applies to one sodium atom applies to them all. The point of theory building in the hard sciences is to discover the one explanation that applies across the board. The partial and conflicting models of Laurel[24] must be rolled up into one generalizable paradigm.

In contrast, education and instruction deal with much more complex issues. There are fewer generalities. What applies to one student at one time certainly does not apply to all of them all of the time. This makes theory building a much more tentative endeavor. As Eisner[25] suggests, the most telling aspects of teaching may be lost within the process of the empirical approach. The focus on what is measurable tends to detract from the more ineffable aspects of teaching and learning: this is where Eisner believes the more valuable artistic components of the teaching act reside. Where the natural sciences tend to evolve from multiple paradigms to single predominant models, the sciences of the artificial must always entertain multiple paradigms to fit a multiplicity of situations. Joyce and Weil[26] propose that educators provide a variety of learning environments derived from a variety of models of teaching. The best we can hope for is a collection of explanations and prescriptions anchored to particular kinds of situations.

Gleick[27] and Pagels[28] discuss this in their recent works dealing with chaos and indeterminate systems. They point out that a simulation of a chaotic system such as the weather must be as large and complex as the system being modelled. We are in a similar position, with one crucial distinction: we deal not only with complex and largely indeterminate systems, but also with intention. Our domain is driven by intention,[29] where their systems are driven by immutable physical laws which prevail at the moment.

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23 Simon, *Sciences of the artificial.*

24 Laurel, B. K. (1986). Interface as mimesis. In D. A. Norman & S. W. Draper (Eds.), *User centered systems design: New perspectives on human-computer interaction* (pp. 67-85). Hillsdale, NJ: Lawrence Erlbaum Associates.

25 Eisner, *Educational imagination.*

26 Joyce, B., & Weil, M. (1980). *Models of teaching* (2nd ed.). Englewood Cliffs, NJ: Educational Technology Publications

27 Gleick, *Chaos.*

28 Pagels, H. R. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity.* New York: Simon and Schuster.

29 I suppose our systems in the sciences of the artificial are also ultimately driven by immutable physical laws, but concentration on that aspect of understanding might not prove very helpful in aiding student learning, much like the computer explanations based on bit-shuffling mentioned earlier.

NOTIONS OF SCALE

One final note. I am still troubled by the notion of scale. Let me provide three examples of what I mean. The first is the Mandelbrot series,[30] a mathematical model of fractional dimensions (like the *two and one half* dimension). One example is a fractal, like the image of the dividing line between the water and the land at a sea coast. This is an example of where Reigeluth's zoom lens analogy does not work.[31] The more you zoom in on the line between the water and the land at a seacoast, nothing happens. Its contour looks the same at any scale, from macroscopic to microscopic. Interestingly enough, it is also infinitely long: the smaller the unit of measure, the longer it gets. Imagine using a one-mile long unit of straight lines to plot the points on the seacoast. Then imagine using a one-inch line. The resulting coastline gets much longer. At the scale of grains of sand, it is longer yet. And so on.

Another example which I find charming comes from the *Hitch Hiker's Guide to the Galaxy*.[32] In this novel, the author describes an incident with an interplanetary invasion fleet that attacks the Earth ... and flies right into the mouth of a rather large dog! It was all a matter of scale, you see.

The final example is Gleick's Volkswagen.[33] Gleick describes our perception of a Volkswagen parked on a hill, and points out that it is a VW only if viewed from the right distance. Reigeluth's zoom lens has to be set just about right for us to perceive the car. Zoom out too far and it becomes a mere bump on a hill. Zoom in too far and it is a round, smooth piece of colored metal (like a piece of the fender). Zoom in more, and it becomes a pebbled surface of plastic paint ... or a molecule ... and so on.

Strangely enough, in the first example of the seacoast, the scale did not make much difference in the nature of the image. In the other two, the scale is crucial.

In an educational (or epistimological) sense, this notion could be related to an enormous elaboration structure with cosmology or the notion of a "thing" at the top and quarks with charm (or whatever the *new* elemental particles are) at the bottom. Everything that exists might possibly be placed within this conceptual elaboration hierarchy, but what makes it effable is the scale from which we choose to view it. This again is like explaining computers through bit-shuffling. Pick a spot. Zoom to just the right Reigeluthian point. Explore what, at that scale, is meaningful.[34]

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30 See Gleick's *Chaos* for an explanation and striking series of colour photographs.

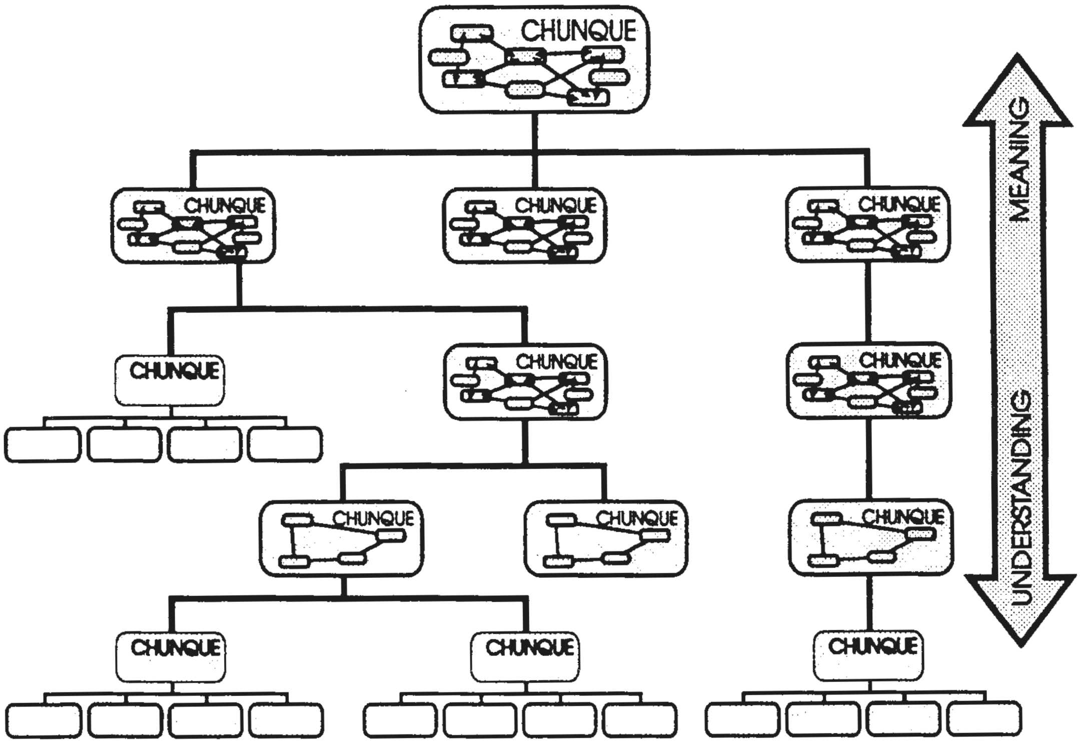
31 Reigeluth, C. M. & Curtis, R. V. (1987). Learning situations and instructional models. In R. M. Gagne (Ed.), *Instructional technology: Foundations* (pp. 175-206). Hillsdale, NJ: Lawrence Erlbaum Associates.

32 Adams, D. (1990). *Hitch Hiker's guide to the galaxy*. New York: Penguin Books.

33 Gleick, *Chaos*.

34 This sounds a lot like Minsky's "move in for a closer look."

This meta-elaboration hierarchy does provide an insight into meaningful understanding. It would seem that no matter which spot you pick as a starting point, if you move up, towards the cosmos, you will gain context: meaning. If you move down, you will discover detail: understanding.



But an elaboration chart can be turned upside down. Then it becomes like a Gagneian prerequisite hierarchy from quarks to cosmology.[35] If you move up the hierarchy, toward the quarks, you discover detail: understanding. If you move down, toward the cosmos, you discover context: meaning.

As Janis Joplin once said, "It's all the same thing, man."[36] Not only must we determine where to set the Reigeluthian Zoom, but also which way up to hold the camera. Minsky suggests we probably zoom, tilt, and pan a lot more than our current theories recognize as we strive to find both the meaning and understanding of our complex existence.[37] Should we start with understanding, then zoom out to meaning? Or vis-versa?

Consider the nature of a Chunque of instruction. It certainly appears to be a moving target. A chunque seems to be scale-dependent. Remember the boy scouts badges? Tying several knots would still seem an appropriate Chunque for which a badge could be awarded. But the special education people might see the accomplishment of passing one line over the other as a major achievement for one of

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35 Gagne, R. M., & Briggs, L. J. (1979). *Principles of instructional design* (2nd ed.). New York: Holt, Rinehart, Winston.

36 From a Janis Joplin concert, "The Festival Express", McMahon Stadium, Calgary, Canada. This is also on a live recording "Janis Joplin in Concert", Side 2, Cut 4 "Ball and Chain".

37 Minsky, *The society of mind.*

their disabled charges, certainly worth much more in that context than the boy scout badge from all of the knots.

I don't have an answer to this dilemma of context-sized Chunques, but it seems to depend on scale. We as learning systems designers will have to choose the scale to match the goals and determine within that context where the split between the value-laden and technical curriculum occurs. But, in my recent experience, it does always seem to occur. And that is the point where we set the primary chunque, the smallest meaningful piece of content within the context of the moment.

FURTHER READING

The books in this list have been recommended by the reviewers of this work and my dissertation committee as significant works which relate to the themes presented here. The first two are on systems theory, the next two on meaning and understanding, the last on holograms as a metaphor for knowledge representation. I have not read any of these yet.

Checkland, P. B. (1981). *Systems thinking, systems practice.* New York: Wiley.

Checkland, P. B. (1981). *Soft systems methodology in action.* New York: Wiley.

Davidson, D. (1984). *Inquiries into truth and interpretation.* New York: Oxford University Press.

Quine, W. V. O. (1960). *Word and object.* Cambridge: M. I. T. Press.

Wilburn, K. (1983). *Holographic paradigms.* Salinas, CA: Intersystems Publications.

These books are from outside the normal realm of learning systems design and instructional design. I feel they add a significant new perspective to what we are all about, and would highly recommend them all. They form the basis of this work.

Gleick, J. (1987). *Chaos: Making a new science.* New York: Viking Penguin.

Minsky, M. L. (1985). *The society of mind.* New York: Simon and Schuster.

Norman, D. A., & Draper, S. W. (Eds.). (1986). *User centered systems design: New perspectives on human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

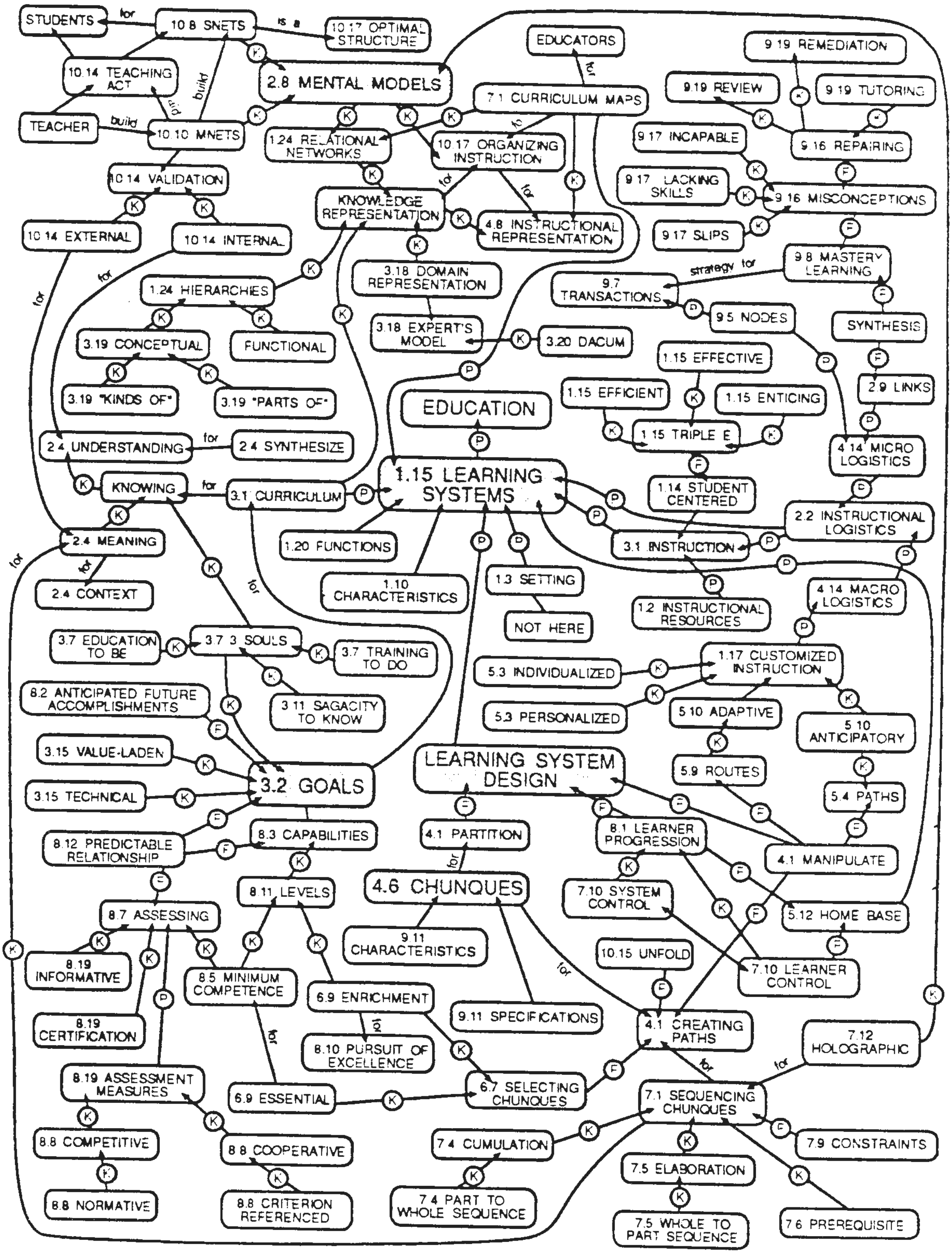
Pagels, H. R. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity.* New York: Simon and Schuster.

Persig, R. M. (1984). *Zen and the art of motorcycle maintenance.* (2nd ed.). New York: Morrow.

Roueche, J. E., & Baker, III, G. (1986). *Access and excellence.* Washington: American Association for Community and Junior Colleges.

Shuell, T. J. (1990). Phases of meaningful learning. *Review of Educational Research. 60* (4), 531-547. (This entire issue of Review of Educational Research is significant).

A MAP OF THE TERRAIN OF LEARNING SYSTEMS



Instructional Logistics and Chunque-based Learning Systems

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